A webcomic of romance, sarcasm, math, and language
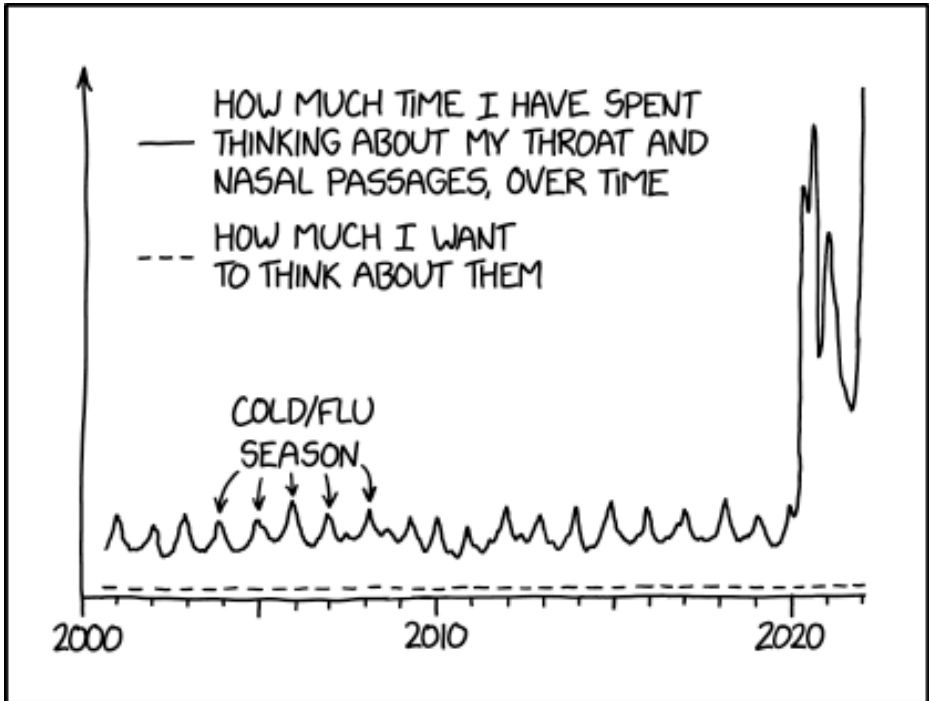
xkcd

RANDALL MUNROE

2022

xkcd

2022

a collection of 156 webcomics

from #2563 to #2718

by Randall Munroe

#2563: Throat and Nasal Passages

January 03, 2022

I always felt like what the 'you are now aware of your tongue' thing needed in order to be truly enjoyable was an element of mortal peril.

Explanation

This comic is another in a series of comics related to the COVID-19 pandemic. This comic became the last to reference the pandemic for a long time. The next reference to COVID-19 came four months later and in 2615: Welcome Back it was just briefly mentioned in the title text.

In the graph a black solid line displays how much he has been thinking about his throat and nose since 2000 and up until 2022. The first 20 years the graph oscillate up and down once every year, and every spike represents the common cold and flu season. Autumn and winter causes the spike, while spring and summer clearly drops. Perhaps this is indicating no tendency to suffer from hayfever, which might at least produce mini-spikes at the times of of maximum grass-pollen, tree-pollen and/or other similar atmospheric flotsam. There is basically a spike for every year, although some years it looks a bit different which could be variations induced by complex sociological or meteorological drivers - meeting more or fewer people inside stuffy buildings rather than in the open air. But all in all the peaks seem low, especially when compared to how much time he has thought about it since the COVID-19 pandemic broke out around March 2020. Each summer since there has been a dip, but not anywhere close to the tops of the previous years, and around New Year 2022 the graph peaks (likely due to the Omicron variant).

The peaks in 2020 and 2021 (2022) are about 6 times higher than those the year before 2020. So if the Y-axis begins at zero, this is how much more he thinks of his throat now than during the times when he actually had a cold.

There seems to be no way of knowing if Randall has had COVID-19, but from his comics it seems safe to assume he is fully vaccinated. At the time of release the Omicron variant of COVID-19 seems to by-pass the protections given by vaccines for about 50% of those vaccinated, although vaccinated people generally do not experience severe symptoms.

The joke is in the dotted line at the very bottom of the graph which either is just above zero, or is actually supposed to be the zero line (which would not change the above assumption about 6 times more thinking). This line reflects how much time he actually wishes to think about them, which is probably not at all. But even before corona Randall seems to have spent way too much time pondering his sore throat.

In the title text Randall references the trick known as "You are now aware of your tongue", which is a self-fulfilling prophecy because it will make anyone hearing it involuntarily think and be aware of their tongue. In a much earlier comic, 972: November, this trick was the topic, see more about it there.

Randall sarcastically remarks that the tongue trick needed an element of mortal peril to be truly enjoyable,

as with the corona pandemic making him aware of his throat and nasal passages. His actual opinion is probably the opposite, that it was annoying before and that it only became worse now that it contains the danger of death. Being aware of your tongue is annoying, but not dangerous. Being aware of your throat during the COVID-19 pandemic may leave you fearing for your life, even if there is nothing wrong with your throat.

Randall has before the corona pandemic complained about a sore throat caused by the common cold, see 1612: Colds, more than once just a few weeks apart, see 1618: Cold Medicine. See also 1896: Active Ingredients Only.

#2564: Sunshield

January 05, 2022
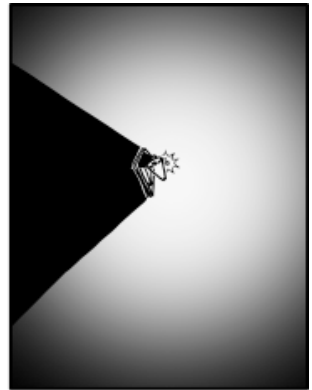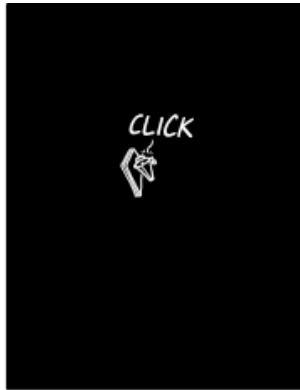
ASTRONOMY FACT: THE PURPOSE OF THE JWST SUNSHIELD IS TO PROTECT THE SUN AND THE EARTH FROM THE TELESCOPE'S POWERFUL FLASH.

RIP the surface of Mars

Explanation

This is another comic with a Fact, though not a Fun fact - this time an Astronomy fact. The next comic with a fact, namely 2596: Galaxies, was also with an Astronomy fact. This is the first time that the field that a fact pertains to has been immediately repeated.

JWST stands for James Webb Space Telescope, a space telescope that was launched 12 days prior to publication of this comic, see more details here 2559: December 25th Launch.

It has a sunshield to protect its instruments from the heat of the sun and to keep them below 40 K (-233 °C/-388 °F). Deployment of the sunshield was completed the day before the comic was published. The JWST has to undergo a complex sequence of deployment steps to unfold parts that had to be packed tightly for launch. This sequence has 344 possible points of failure that would render the very expensive space telescope useless; 75% of them led up to the successful full deployment of the sunshield. Thus successful steps are widely celebrated, with this comic an example of such a celebration.

Ordinary cameras use a flash to take pictures in low-light situations. Outer space is very dark [citation needed] (one of the JWST's mission objectives will help astronomers calculate exactly how dark), so this comic posits that the JWST has a very powerful flash to

compensate for this. Most astronomical cameras don't use flash photography [citation needed] -- they depend on the light either emitted by objects themselves (e.g., stars) or from nearby very bright objects (e.g., Solar System planets will reflect the Sun's light, while distant clouds of gas and dust may be largely illuminated by the light of supernovae or recently formed stars within or near them). A flash generally doesn't work for many reasons:

- It would take too long for the light of the flash to return to the telescope - at least twice the time that it had already taken for the original image to arrive on its own.
- The clicking sound indicates that the JWST is using a camera with mechanical parts that are moving in order to take a picture. This can be a mirror of a single lens camera, where the clicking noise is produced by the mirror moving away to allow the light to reach the sensor. Alternatively the shutter in front of the sensor produces a clicking noise when it is opening to start the exposure. In the latter case the opening of the shutter would happen before the flash is emitted, so light from the flash wouldn't even reach the camera's image sensor. It is however possible that the camera is using a time exposure and that the shutter was still open when the flash occurred.
- Not enough 'flash' light would return due to it uselessly spreading in all directions. Instead, in a telescope mirrors and/or lenses focus the light, and long exposure

times are used to collect enough of the current light to form a decent image.

- A flash powerful enough to overcome the previous difficulty would have to be inordinately powerful. This would raise significant questions about powering it, its destructive effect on JWST, and its damage to (or at least disturbance of) many of the things the flash would be able to illuminate.

- The objects and phenomena of interest of JWST are, by dint of their extreme distance, being seen as they were in the early stages of the universe, and emit light that potentially gives vital clues about that era, only marginally this side of the current visible-horizon of our apparently expanding universe. Should our flash ever reach them (assuming they still exist) and we have the patience to await the return (assuming we still exist), this will only reveal the much older versions of whatever they have become and only in the form of light that we have swamped them with.

- Before this, any intervening civilization that possesses (or can still develop) the necessary capabilities will have at the very least responded, if not retaliated, to the original flash. Their response might be far less humorous.

There are some examples of astronomical research done using things similar to a flash. Radar astronomy involves emitting radio waves (microwaves) that bounce off distant planets, asteroids, comets, etc., and analyzing the returned waves. The Lunar Laser Ranging experiment uses lasers, which are loosely related to flashes for

photography, to measure the distance between Earth and Moon. The outward light is concentrated upon the approximate area of the lunar target, which employs an optical trick to send most of that which actually struck it back to the approximate area of the source equipment.

The comic assigns the sunshield a new, comical purpose of shielding the Sun (and Earth ,which is roughly in the same direction as the Sun, due to the deployment at the L2 Lagrange point) from this flash, rather than the other way around. When the camera is taking a picture, the comic shows space in front of the shield lit up while there is a totally dark shadow behind the shield (in the direction of Earth and Sun).

The comic also has the camera making a "click" sound. In traditional mechanical cameras without a mirror, this sound comes from the shutter opening and closing, and mirror-less digital cameras mimic this sound so the user (and subject, when human) knows when the picture is being taken. JWST won't actually click -- it doesn't have a shutter, as it takes long-exposure digital images, and in space no one can hear you click.
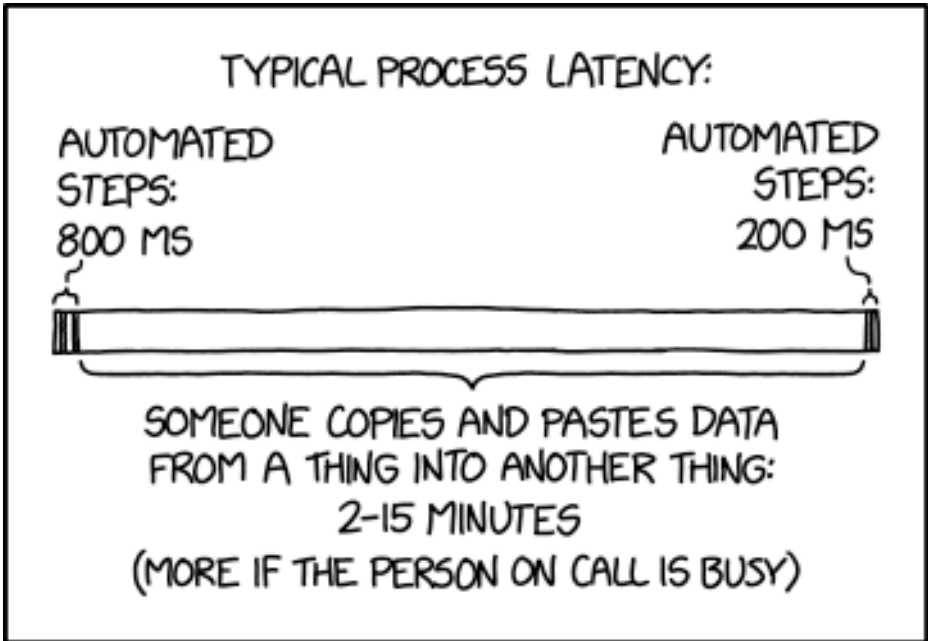
The telescope also tells the universe to smile for the picture. The universe doesn't have a mouth to smile with[citation needed], although there are a number of features both on Solar System objects and in deep space that look like faces; this is a phenomenon called pareidolia. The most well known is the Man in the Moon, but there are numerous others both in the Solar system, most famous is probably the Face on Mars and

out among the galaxies, like the Cheshire Cat galaxy group named after the Cheshire Cat from Alice in Wonderland.

The title text suggests that, due to the sunshield not being angled to shield Mars, Mars's surface has been badly scarred by the flash. This implies incredible strength of the flash, perhaps to ensure the light can return from its destinations, comparable to death-ray satellites in fiction.

#2565: Latency

January 07, 2022

TYPICAL PROCESS LATENCY:

AUTOMATED STEPS: 800 MS

AUTOMATED STEPS: 200 MS

SOMEONE COPIES AND PASTES DATA FROM A THING INTO ANOTHER THING: 2-15 MINUTES
(MORE IF THE PERSON ON CALL IS BUSY)

Each SCAPDFATIAT point increases the chance that the process will involve the phrase 'by the next business day.'

Explanation

This comic is about the time it takes for a request to be processed; a total of 1 second is devoted to automated processes, but 2-15 minutes or longer are devoted to a not-yet-automated process that is performed by a human.

Part of the humor comes from the fact that most, if not all, instances of a person copying and pasting data from one place to another could be trivially automated and included as part of the automated steps, if only a programmer could take the time to program the process. Having a human take several minutes to move data that a computer could move in fractions of a second is incredibly inefficient, and reflects the humorously poor optimization present in many routine processes.

The title text refers to SCAPDFATIAT, which is defined in the comic as Someone Copies and Pastes Data From a Thing Into Another Thing.

Because it requires a human worker to fully accomplish, in-between various other work commitments as well as possibly personal/non-work activities, it is plausible that (even if the copying was started promptly enough) the person involved will not have pasted onwards by the time their effective working day ends. It might be reasonable to assume that a job that ought to take no more than a few actual minutes thus is only 'guaranteed' to be concluded at some point the following working day

(which may be a whole long weekend away, possibly including public holidays). The business will therefore state (e.g. in contractual service agreements) that the guaranteed response times are of the order of "within one working day". Even if they hope and expect that any request passed to their staff is handled within a much shorter timescale. If reliably capable of being fully automated (e.g. with a resilient and continually maintained server infrastructure), could be fulfilled almost instantly at any time of day or night. But it may be the need to keep an 'intelligent' human in the loop (as well as to "under-promise and over-deliver", rather than the reverse) that makes the concept of "next-working-day" a more attractive commitment to make.

#2566: Decorative Constants

January 10, 2022

EQ. 4-15

$$T = \mathbb{D} m_o \left(r_{out} - r_{in} \right)^{\bar{\mu}}$$

T: NET RATE

m_o: UNIT MASS

$(r_{out} - r_{in})$: FLOW BALANCE

$\mathbb{D}, \bar{\mu}$: DECORATIVE

MATH TIP: IF ONE OF YOUR EQUATIONS EVER LOOKS TOO SIMPLE, TRY ADDING SOME PURELY DECORATIVE CONSTANTS.

Arguably, the '1/2' in the drag equation is purely decorative, since drag coefficients are already unitless and could just as easily be half as big. Some derivations give more justification for the extra 1/2 than others, but one textbook just calls it 'a traditional tribute to Euler and Bernoulli.'

Explanation

This is another one of Randall's Tips, this time a Math Tip. Randall gives an example of a complex-looking equation labeled 4-15:

But since and $\bar{\mu}$ are "decorative", the equation can be reduced to:

Here, T is the net rate, m0 the unit mass, and (rout − rin) the flow balance.

The decorative symbols can be interpreted as constants = $\bar{\mu}$ = 1, in which case the implied operations of multiplication and exponentiation make sense. The is double-struck ("blackboard bold", thus in the comic only the vertical line is double). Mathematicians, who are always searching for more symbols[citation needed], have taken to distinguishing things represented by the same letter by using different fonts, such as , , , , , , , , , , ∂, , and . The double-struck font is easier to write on a blackboard than a proper bold letter and often represents a set, such as for the set of real numbers or for the set of complex numbers. can represent the unit disk in the complex plane, the set of decimal fractions, or the set of split-complex numbers.

μ is the Greek lowercase mu and has many uses in mathematics and science. Here it has a bar, $\bar{\mu}$, which could indicate a number of things, including the complex conjugate. Intriguingly, μ is the symbol in

statistics for the population mean, and the overbar represents the sample mean, so this could represent a random variable which is the average of a sample of means μ_i of different populations in some larger ensemble of populations. Using a special version both of D and μ to even further spice up the formula all leads up to the math tip.

Other examples of well known equations that are profound but look simple include:

• $E = mc^2$ (Special Relativity),
• $PV = nRT$ (the Ideal Gas Law),
• $F = ma$ (Newton's Second Law),
• $V = IR$ (Ohm's Law),
• $G\mu\nu + \Lambda g\mu\nu = \kappa T\mu\nu$ (Einstein field equations), and
• $e\pi i + 1 = 0$ (Euler's Identity).

Of these, only Einstein field equations have been spiced up with decorative indices (which actually hide a system of ten nonlinear partial differential equations). Euler's identity is massaged to include both 0 and 1 (since including both the additive and multiplicative identities is "more profound") since the interpretation of $e^{i\pi} = -1$ is otherwise not necessarily intuitive; using the ratio of a circle's circumference to its radius () rather than its diameter results in $e^{i} = 1$ which can be interpreted as a statement that "one trip around the circle leaves you back where you started".

In the title text, Randall mentions the Drag equation,

which is attributed to Lord Rayleigh. In fluid dynamics, the drag equation is a formula used to calculate the force of drag experienced by an object due to movement through a fully enclosing fluid. The equation is $F_d = \frac{1}{2}\rho u^2 c_d A$. Here F_d is the drag force, ρ the mass density of the fluid, u the relative flow velocity, c_d the drag coefficient and A is the area.

Randall jokes that the factor of ½ in the equation is meaningless and purely decorative, since the drag coefficients, c_d, are already unitless and could just as easily be half as big thus leaving out the ½ in front of the equation. The ½ is thus just an example of a "decorative constant." The usual reason for including the factor of ½ is that it is part of the formula for kinetic energy that appears in the derivation of the drag equation, i.e. $\frac{1}{2}\rho u^2$. However, modern treatments are so condensed that this factor of ½ is often smuggled in with no explanation.

Since we can choose the constants to be whatever we want, it could be possible to absorb the ½ into the drag coefficient c_d, but that does not mean it is unmotivated, since it comes from the kinetic energy. Still, Randall quotes Frank White's Fluid Mechanics textbook, which two times calls it "a traditional tribute to Euler and Bernoulli." According to White, the factor of ½ rather comes from the calculation of the projected area of the object being dragged. Randall has brought up this point before, in his book, "How To".

The line from White probably refers to renowned mathematicians Leonhard Euler and Daniel Bernoulli.

Euler who is held to be one of the greatest mathematicians in history worked directly with Daniel and was a friend of the Bernoulli family, that produced eight mathematically gifted academics. Bernoulli is known for modifying the definition of vis viva (what we now call kinetic energy) from mv2 to ½mv2, as motivated by the derivation from the impulse equation. In 1741, he wrote

That is, "define vis viva to be ½ mv2 = ∫pdx," where p is the force (from pressione) and dx is the differential of position (infinitesimal displacement). Today, this equation says that the kinetic energy imparted to an object at rest equals the work done on it. In the drag equation ½ ρu2 represents the dynamic pressure due to the kinetic energy of the fluid, and hence the 1/2 makes sense to keep in the equation, and could thus easily be argued not to represent a decorative constant.

The title text is pretty much word-for-word a repeat from Randall's book How To. In Chapter 11: How to Play Football, he misuses the drag equation, and mentions this fact in more depth, in a footnote.

#2567: Language Development
January 12, 2022

The worst is the Terrible Twos, when they're always throwing things and shrieking, "forsooth, to bed thou shalt not take me, cur!"

Explanation

Megan and Cueball are having what could appear to be a typical conversation about her child's ability to learn languages really fast. But for the joke, the comic mixes up two possible meaning of "language development:" the development of an individual person learning a language, and the development of languages themselves over time.

The conventional meaning of language development is the process by which infants begin to talk, that is to understand and produce intelligible speech. The field of language acquisition (sometimes called... language development) seeks to understand how baby humans are able to rapidly comprehend, internalize, and begin producing a new language.

Instead of starting with babbling, the first stage of normal language development, this baby's form of "language development" seems to be the linguistic form: going through all of the theoretical stages of the evolution of the English language, from Proto-Indo-European to Germanic to Old English.

In comparative linguistics and historical linguistics, Proto-Indo-European is a theorized common ancestor of the Indo-European language family. Proto-Germanic is a reconstructed language formerly spoken in Iron Age Scandinavia. It developed out of Proto-Indo-European and is the proposed common ancestor for all Germanic languages. Old English would have developed out of

Proto-Germanic. Modern English developed out of Old English with many additions from French (which comes from a different branch of the Indo-European language family).

This parody of language development parallels the discredited theory of recapitulation in embryo development, sometimes expressed as "ontogeny recapitulates phylogeny", in which a developing animal embryo (ontogeny) was once thought to go through stages resembling successive adult stages in the evolution of the animal's remote ancestors (phylogeny). It also plays off of misconceptions about language evolution. Many people assume that ancient languages are more "pure" and "primitive" and that modern languages are more "complex" and "advanced". The comic takes this idea to its logical conclusion by joking that children should successively graduate between historic languages while learning to speak, which is more obviously absurd — it would take years to acquire any of the languages involved.

In linguistics, reconstructed words from proto-languages are commonly marked with an asterisk (*) to show that the word forms are not attested by any historical sources but created as a proposed ancestor word. The baby says the Proto-Indo-European roots that the words "milk" and "please" are derived from. Obviously, the speakers of Proto-Indo-European did not speak in roots, but used words made from the roots, so the way the baby talks does not reflect an obvious stage of the proto-language's fully formed use (although it may happen to reflect some

historic protolinguistically-raised infant's personal linguistic step on the way to eventually attaining a full protolinguistic fluency).

Some sounds babies make are hard to interpret.[citation needed] However, humans have a tendency to recognize known things and patterns. They see what they want to see and hear what they want to hear. Thus, a parent familiar with Proto-Indo-European may falsely hear their baby speak Proto-Indo-European by misinterpreting unintelligible sounds.

Perhaps this is an alternate universe where every baby has to gradually develop their language skills along a historical path rather than a child-developmental one, until they reach the ultimately developed modern language of their parents (in this case Modern English).

There have been alleged language deprivation experiments where newborn infants were not exposed to any spoken language in order to find the "natural human language", in the days before ethics review boards would have forbidden such cruel treatments. Such experiments are known today to be a source for psychological problems at least. Alleged outcomes in the apocryphal sources range from the deprived children imitating other sounds in their environment, to them dying.
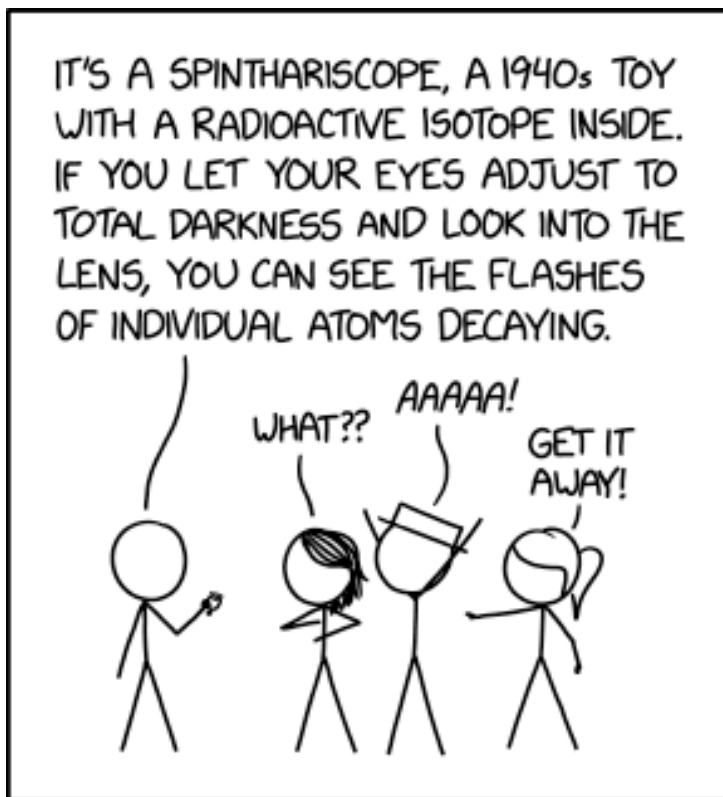
In the title text, Randall describes a 2-year-old child as speaking in iambic pentameter and in Elizabethan English, a meter and dialect of modern English used by Shakespeare more than 400 years ago. The Terrible Twos

are a colloquialism referring to the developmental tendency of two-year-olds to have more temperamental behavior, as the child's developing assertion of autonomy and self-identity clash with other expectations of behaviour, before hopefully acceptably balancing their assertiveness with social normatism. The toddler's quote of "forsooth, to bed thou shalt not take me, cur!" would roughly be equivalent to "Indeed, you shall not take me to bed, you dog!" in less archaic English.

#2568: Spinthariscope

January 14, 2022

IT'S A SPINTHARISCOPE, A 1940s TOY WITH A RADIOACTIVE ISOTOPE INSIDE. IF YOU LET YOUR EYES ADJUST TO TOTAL DARKNESS AND LOOK INTO THE LENS, YOU CAN SEE THE FLASHES OF INDIVIDUAL ATOMS DECAYING.

WHAT??

AAAAA!

GET IT AWAY!

FUN FACT: SPINTHARISCOPES HAVE THE HIGHEST RATIO OF "THAT CAN'T POSSIBLY BE SAFE AND LEGAL" TO ACTUAL SAFETY AND LEGALITY OF ANY KNOWN TOY.

Other high scorers are melt-in-your-hand aluminum-destroying gallium and tritium-powered glowsticks. Lawn darts are toward the other end.

Explanation

This is another comic with one of Randall's fun facts. As stated in the comic, a spinthariscope is a device with a small amount of radioactive material (americium or thorium) and a screen. When one of the radioactive atoms decays, it emits an alpha particle, which strikes the screen, which emits a small flash of light. You can see these flashes by looking through a lens. It was invented in 1903 initially as a scientific instrument but was soon replaced by more accurate and quantitative devices. But the original device was still popular for some time as an educational toy for children, and you can still get them today in some places.

The joke in the comic is that most people have little understanding of radiation and overreact to any mention that something is radioactive. So, when Cueball tells Megan, White Hat, and Ponytail that the toy contains radioactive material, they're shocked and scared. But the amount of radioactive material in the toy is very tiny and the radiation is itself so trivially contained that there's practically no risk from it. The short-ranged alpha particles are likely stopped by the lens through which the harmless flashes of light (from particles that instead hit and neutralise in the internal screen element) are seen.

The fun fact in the caption says that Spinthariscopes have the highest ratio of "that can't possibly be safe and legal" to actual safety and legality of any known toy. When people hear about Spinthariscopes for the first

time, they often assume, due to the radioactive material inside, that they must be extremely dangerous. They thus also question if such a toy is at all legal to make or own in the first place. But the fact is that Spinthariscopes are both safe and legal to make, sell and own in the United States. So, the perceived danger and presumption that it must be illegal is at an extremely high number, and the actual danger and the actual illegality results in a very low number on the same scale. It is this ratio between perceived and actual danger and illegality that are the highest for Spinthariscopes, higher than for any other known toy.

The formulation, however, causes some confusion, because the caption uses actual safety and legality (high) instead of actual danger and illegality (low). Instead of a high ratio between perceived danger and actual danger, the result is an even ratio between perceived danger and actual safety, which are both high. The ratios for the other mentioned toys would also be even, as they have low perceived danger and low actual safety. This is obviously not the intended meaning, as the other toys are said to be toward the other end of the scale.

The title text mentions some other materials/toys that sound dangerous but aren't. Gallium is a metallic element with a low melting point of 29.76°C (85.568°F) so it will melt in your hand. Additionally, gallium has strange properties when it interacts with aluminum, causing aluminum to "melt" or become brittle. Tritium is a radioactive isotope of hydrogen, but can be used to create glowsticks and other lighted objects. Though these

two toys might seem dangerous, they are actually typically used perfectly safely.

At the opposite end of the spectrum is lawn darts, a toy containing large darts that are thrown into the air to fall back down onto a target that's placed or marked upon the ground quite near the players' positions. Unlike the spinthariscope, which sounds dangerous but is actually harmless, lawn darts sound relatively innocent but can cause severe injury if you accidentally hit a person (and a few children were even killed), so they were banned in the US and Canada in the 1980s. When sharpened, these toys even compare quite favorably to antique weapons of war. Today, many houses have smoke detectors using ionization caused by radioactive decay of Americium-241 to detect the smoke. So having something with radioactive material in your house is quite common, and in this case increases the safety level for those houses.

#2569: Hypothesis Generation

January 17, 2022
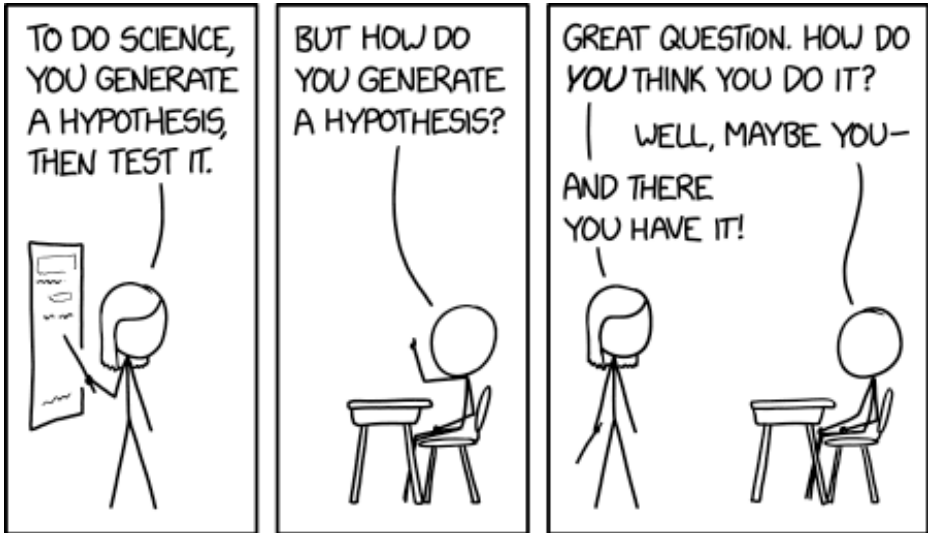
Frazzled scientists are requesting that everyone please stop generating hypotheses for a little bit while they work through the backlog.

Explanation

Miss Lenhart is teaching a science class and starts by formulating the fact that to perform any science you need to generate a hypothesis in order to test it.

The front row student, Cueball (presumably the rest of the students in the class are off panel), is thus prompted to ask the salient question of how one finds an original hypothesis. By using a clever prompting question in reply, Miss Lenhart allows the student to discover the answer himself. In typical Miss Lenhart fashion she is a bit rude, interrupting him before he can even formulate his thoughts. But the idea that he even has gotten an idea to share is proof that he has made a hypothesis about how to generate a hypothesis. This does not, however, answer how he did it, but now he knows he can do it.

This approach may not have worked with less eager/capable students, so it highlights the strengths of both the student and the teacher - and that she had a good understanding of the student's ability to reason this out with just the barest of guidance. Or perhaps it is just another prank by Miss Lenhart.

The key aspect being conveyed in this simple exchange is that one of the many good practices in science (no matter the aspect, though the specifics may change according to the precise field of study) is that one should first have an idea of what you can test and then perform the test to confirm (or rule out) your idea.

In the title text the joke is that it is thus very easy to make hypotheses and thus everyone makes them all the time, so there are numerous ones to test. And the now frazzled scientists that are trying to work their way through them request that everyone stop making new hypotheses until they have worked their way through the huge backlog of untested hypotheses already made.

#2570: Captain Picard Tea Order

January 19, 2022
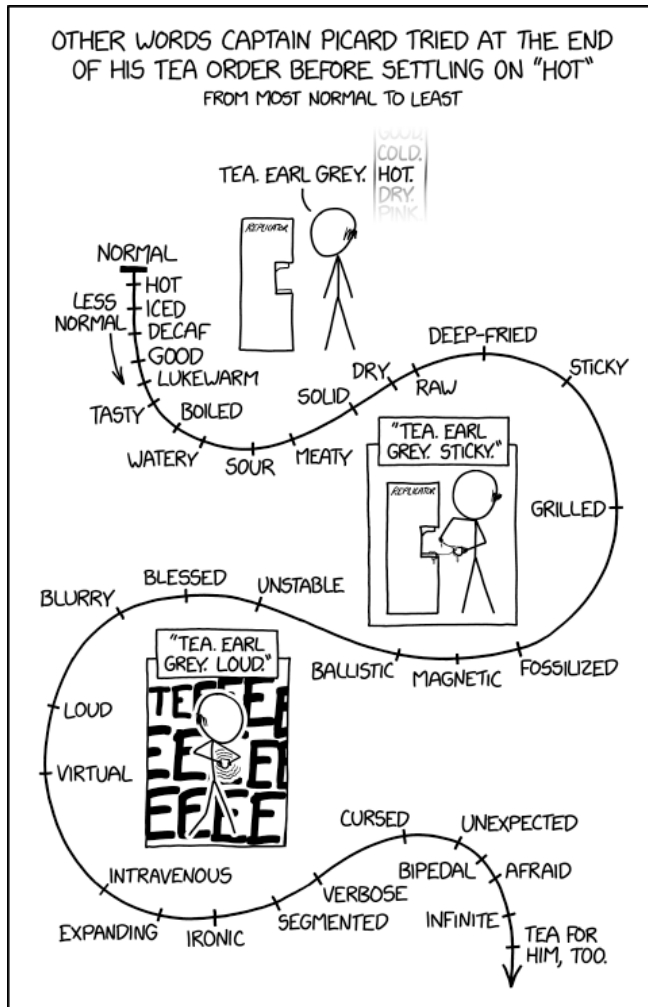
We can ask the Earl for his order once he's fully extruded from the dispenser.

Explanation

Captain Jean-Luc Picard is a primary character in the science fiction TV series Star Trek: The Next Generation, which is focused on the crew of a starship. The ship is equipped with replicators, which can create virtually any object or material requested, including food and drink, and which respond to verbal commands.

In the show, Picard's beverage of choice is Earl Grey tea. His habitual method for ordering is to first specify what he wants (tea, in this case), then specify a particular type (Earl Grey), and then give specific instructions for how it is to be served (hot, as opposed to iced tea). Because this is his favored drink, he repeatedly places the exact order "Tea. Earl Grey. Hot." The first picture in the strip implies that the display shows each part of the order, and provides a list of options for the next step.

Randall parodies this repeated order by suggesting other words that could follow "Tea. Earl Grey.", starting from ones he considers more "normal" moving to those he presumes increasingly "less normal" down a long and winding arrow.

The results of two examples from the normal/less-normal scale are also illustrated: Sticky tea and loud tea. Sticky is kind of obvious, though perhaps not immediately understandable, the loud version is a tea that screams "Teeee..." The vibrating and screeching teacup may be a reference to the various Star Trek

episodes about tribbles, which behave in a similar way in the presence of Klingons.

The very last qualifying addition, the least normal is not a single word but "Tea for him, too." This reinterprets the meaning of the standard introductory words, suggesting that "tea", and "Earl Grey" are separate orders, which implies that he wants the replicator to produce tea, then replicate a human being named Earl Grey (either one of the Earls Grey or a person surnamed Grey with the given name of Earl), then a second tea to serve to this newly created person. Earl Grey tea is named after the Charles Grey, 2nd Earl Grey, a 19th century British Prime Minister, and Captain Picard possibly wishes to have said Earl be generated to provide him with company.

In contrast to the often trivial use of a replicator as merely a potentially infinitely versatile vending machine, the comic sets up a number of quite esoteric options, culminating in Earl Grey himself potentially drinking (generic) tea, after both the tea and he have been replicated into existence by Picard.

In the title text, someone tells Picard that they should wait until the Earl has been fully extruded from the dispenser, and then ascertain what he would actually wish to drink. The presumption is that it could take some time to get a full living person out of the replicator. This sort of operation would be better suited for the holodeck, which has been used to create simulacra of other historical figures, including Stephen Hawking, Albert Einstein, and Sir Isaac Newton, with the

limitations that they are mere simulations without their own autonomy and cannot exist beyond the limits of the fixed holotransmitters; though at least two others seem to have gained full sentience, and granted (or be convinced they were granted) physical freedom.

In the various versions of Star Trek, it's established that replicators aren't capable of producing living things, so canonically this version of the order could not be filled.

Other Words[edit]

#2571: Hydraulic Analogy

January 21, 2022
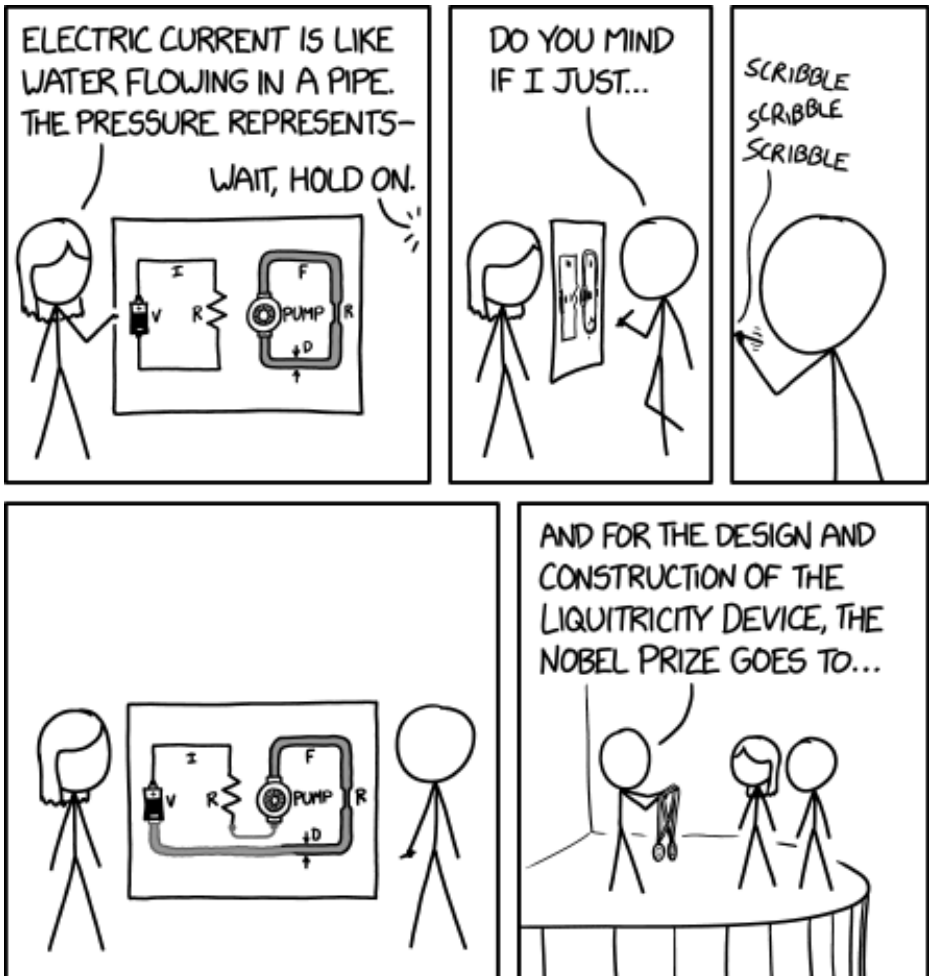
Current (water) running through the water (wires) causes it to boil, increasing the pressure (voltage), but resisting (impeding) the flow of hydroelectricity (water currents). This is the basis for Ohm's law.

Explanation

Electric flow is commonly represented by a "hydraulic analogy". In this analogy, the water pressure represents voltage and the flow of the water is the current. Electric resistance is represented by a constricted section of a pipe.

Miss Lenhart is teaching a class and starts to explain this analogy when Cueball suddenly has an idea and changes her diagrams - connecting the electrical diagram and the hydraulic diagram. In doing this, he has envisioned what comes to be called a "liquitricity device", combining liquid water and electric current flows together and given a suitably portmanteau title.

The last panel shows that Miss Lenhart and Cueball eventually receive the Nobel Prize, presumably the Nobel Prize in Physics, for the design and construction of the device - indicating that rather than being purely theoretical it has actually been practical to make this device.

The title text 'explains' how this device works and references Ohm's Law, one of the fundamental laws of electricity, but strangely seems as much an incomprehensible mix of the two as the diagram in explaining whatever form of possible duality it actually employs.

Randall already mixed water flow and circuit diagrams

over 10 years ago: one of the footer comics, 730: Circuit Diagram, displays a very complex circuit diagram. Although no pump or direct water flow can be found here, it all ends up in a beaker with holy water. And there is a symbol labeled 3 liters, at the bottom close to the beaker. This is the symbol for an orifice or flow restriction used on plumbing or hydraulic diagrams.

#2572: Alien Observers

January 24, 2022
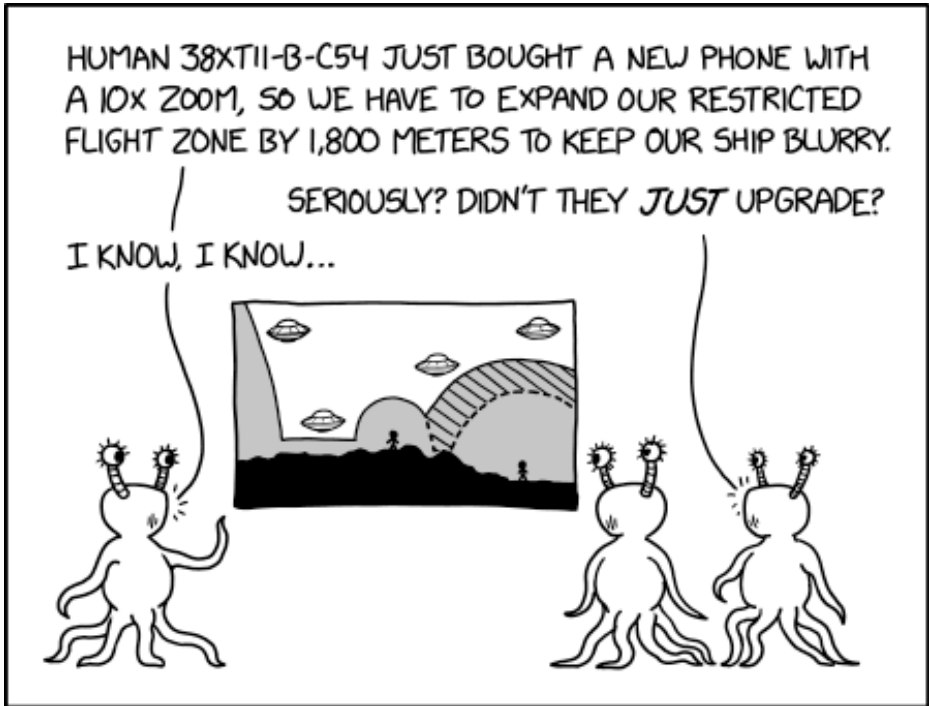
THE HARDEST PART OF BEING AN ALIEN OBSERVING EARTH IS KEEPING TRACK OF WHAT CAMERAS EVERYONE HAS.

ALERT: Human 910-25J-IQ38 has created a Youtube channel. Increase erratic jerkiness of flying by 30% until safely out of range.

Explanation

This depicts a group of aliens observing earth, and discussing their "restricted flight zone", which they appear to change each time a human acquires a more powerful camera. This comic was followed directly by 2573: Alien Mission, where aliens use similar looking flying-saucer type spacecrafts to observe Earth. It is not specifically stated that these two form a series, but the next comic could be seen as a direct follow up to this one, indicating that the aliens are the same in the two comics. Just 7 comics later 2579: Tractor Beam also used similar spacecraft.

Both strips are based on UFO conspiracy theories, which are common in the US and a number of other countries. It is often claimed that Unidentified Flying Objects seen in the sky are, in fact, extraterrestrial space craft, visiting earth for various reasons. Reports of such sightings have existed for a long time, and ever since cameras became widely available, photographs (and later videos) have been produced which are claimed to show such flying vessels. Almost invariably, these images are sufficiently distant, blurry, or otherwise obscured as to make any kind of detailed identification impossible - they could not be Unidentified Flying Objects if it were possible to identify them!

This strip lampoons such ideas by positing that aliens are real, but deliberately maintain a distance such that no clear photographs can be taken. While this concept

might seem initially plausible, it doesn't stand up to examination. Over the past several decades, cameras have become far more common, with most of the population of many countries carrying cameras every waking moment (and even sleeping with those same cameras within reach). At the same time, cameras available to the average consumer have dramatically increased in resolution and zooming capabilities. The same shot that resulted in blurry and vague photographs in early digital photography could result in much more detailed images today, and also overcome many of the pitfalls associated with 'analogue' photography without sufficient skill and/or bulky equipment. What's more, the cameras owned by individual consumers have a wide range of resolutions and other capabilities, meaning that an image that would show little detail from one person's camera could result in highly detailed photograph if someone else took a picture. The fact that improving camera technology has not resulted in improved images of these supposed vessels is an impossibly weak point in these conspiracy theories.

The humorous premise of the strip is that these aliens are real, and are monitoring earth, but are taking deliberate actions to keep evidence of their presence ambiguous. To do this, they would need to not only monitor what camera technology exists on earth, but the exact type of camera each individual owns, and maintain their flights right at the outer visual limit of those cameras. Such information would need to be implausibly detailed, and constantly updated, because technology is constantly

improving, and people are constantly getting new phones with new cameras. Part of the joke is that the aliens would have to know the visual range of our cameras, but instead of remaining safely outside of it (so that no pictures of their vessels could be taken at all), they stay close enough to be seen, but never close enough for detailed images.

In a broader sense, this strip addresses the same issue as previous strips, such as 718: The Flake Equation and 1235: Settled, in which the phenomenon of UFO sightings/reports is still left not resolved (either way) despite what modern technology should suggest is possible. The suggestion is that this trend either means that sufficiently advanced aliens are deliberately leaving ambiguous evidence of their presence, or that no such alien visitors are here, and the purported evidence is either faked, or misinterpretations of other phenomena. It's pretty clear which explanation Randall favors.

The identifier for the one buying the phone begins with "Human 38XT11". This may be a reference to THX 1138 as this was the title of George Lucas's first film, which is also referenced in the original Star Wars film. The name contains the number in reverse, as well as the letters, if "human" could be written as H. Forty comics earlier, in 2532: Censored Vaccine Card, the number 1138 is also used along with another number referencing Star Wars. The aliens appear to be the same lifeforms as seen in the bottom row of 2359: Evidence of Alien Life, and they also have similarities to the illustration in the what if? article Diamond.

In the title text, the aliens note that one particular human now has a YouTube account, meaning they are likely to record video instead of attempting to capture still images. This means that the alien craft used to create the sighting must behave as erratically as possible, in order to avoid being identified. This relates to the often wildly oscillating (as well as blurry) films and videos of 'UFOs' that have been taken by the impromptu human observer beyond the limit of their ability to hold their fully-zoomed camera steady. Here it is explained as the flying saucers actually moving in an improbably jerky manner to prevent detailed recording of their craft. Further briefings of the sort depicted would doubtless accompany upgrades in optical/digital-stability features or the purchase of a camera tripod.

#2573: Alien Mission

January 26, 2022
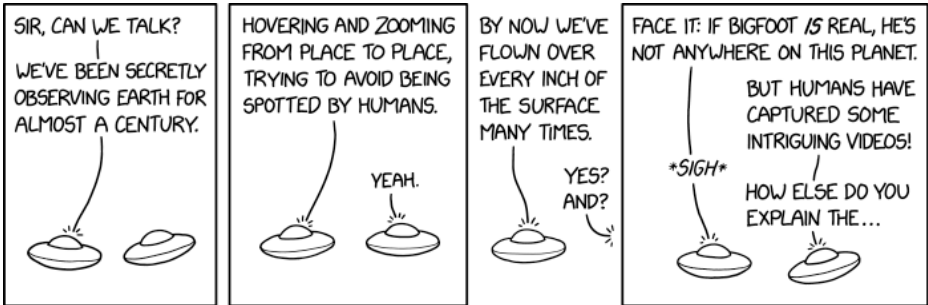
Fine, we can go search the Himalayas for the Yeti ONE more time, but keep a safe altitude over the Pacific and PLEASE watch where you're going. We can't afford another Amelia Earhart incident.

Explanation

This comic followed directly after 2572: Alien Observers, both comics featuring alien flying saucers observe Earth. It is not specifically stated that these two form a series, but this comic could be seen as a direct follow up to the previous one, indicating that the aliens are the same in the two comics. Just 6 comics later 2579: Tractor Beam also used similar spacecraft.

The comic portrays a conversation between aliens inside two flying saucers (or alternately, two aliens whose form is that of flying saucers) in which they discuss their long-secret observation of Earth. It seems that the leader of the mission is in the right saucer, as the alien in left saucer begins by saying "Sir, can we talk". The left alien then continues to state that they have been secretly observing Earth for almost a century (perhaps from the early 1930's or late 1920's, and the title text suggests they already were there in 1937). During these almost 100 years, they have repeatedly flown over every (square) inch of Earth's surface, while trying to avoid being spotted by humans. (This is related to the previous comic, which is about improving cell-phone cameras making it increasingly difficult for flying saucer occupants to avoid being photographed.)

This leads up to the punchline, which reveals that the leader in the right saucer has been hunting for Bigfoot. The left alien tells him that if a Bigfoot exist anywhere in the universe, it is not on planet Earth. Apparently even

advanced aliens have been unable to spot Bigfoot. The alien leader continues his delusion by citing intriguing human videos of something that looks like Bigfoot. When the other alien sighs, implying that this conversation has occurred many times before, the leader continues his arguments with the typical conspiracy line, "How else do you explain the..."

The first panel alludes to the fact that UFO sightings became commonplace only in the 1940s.

The humor derives from the fact that UFO enthusiasts and cryptozoology enthusiasts have a similar mindset: They both believe in phenomena that the scientific establishment believes baseless. Both systems are fully lacking in clear evidence but have an abundance of eyewitness accounts and vague/blurry photographic evidence. And both belief systems have existed for many years, but rapidly advancing technology, accumulating data, and ubiquity of high quality cameras have still failed to capture any clear and detailed evidence. (Randall seems to find this point particularly significant, and although his previous comic explained the bad flying saucer photos, he already made the comic 1235: Settled long ago, where he calls it settled that Bigfoot, UFOs, and similar phenomena don't exist since everyone has a camera handy at all times.) While these concepts are parallel, they're logically independent, as one deals with species that are presumably native to Earth and the other deals with advanced alien species visiting the Earth. The notion of alien visitors being interested in cryptozoology is incongruous: to them, all Earth animals would

presumably seem equally alien.

In previous strips, Randall has suggested playing conspiracy theories off against one another (see 966: Jet Fuel). This comic has a similar theme: suggesting that UFOs are here to search for Bigfoot (and the Yeti) sounds ridiculous on its face. But any explanation of why it's ridiculous would apply equally well to the notion of Bigfoot and UFOs individually.

Some of the aliens clearly have a similar belief, at least in Bigfoot, which is why they came to Earth. This implies that they had some prior knowledge or suspicion of its existence, and only then possibly narrowed it down to this one planet because of the videos humans have made. In 2953: Alien Theories, it is further revealed aliens have a similar interest in UFO conspiracies.

Whatever the arguments about Bigfoot, the title text reveals a separate discussion regarding the Yeti, a similar large hominid purported to reside in the Himalayas, and the tentative permission to conduct one last search for it. As the Yeti and Bigfoot are very similarly described, they could also be seen as the same, so the only difference is that finding a Bigfoot in the Himalayas would make it a Yeti. In the discussion about this last search, they caution about staying high above the Pacific and watch where they are going. This is because, as it turns out, they were the cause of the Amelia Earhart incident. Amelia Earhart disappeared while flying over the Pacific Ocean in 1937 and neither her nor her plane have ever been found. The title text implies that she disappeared because of an

encounter with a flying saucer. She has previously been the main character in 950: Mystery Solved and has since been a recurring theme on xkcd.

That their clearly superior observation technology and methods have been apparently unable to resolve these issues at first seems like it shouldn't bode well for our own cryptozoologists. But since lack of results does nothing to deter them, and since it is always impossible to prove a negative, they would likely not change their beliefs even if they heard of the alien results: "Bigfoot of course hides when the aliens look! And how else do you explain the..."

#2574: Autoresponder

January 28, 2022
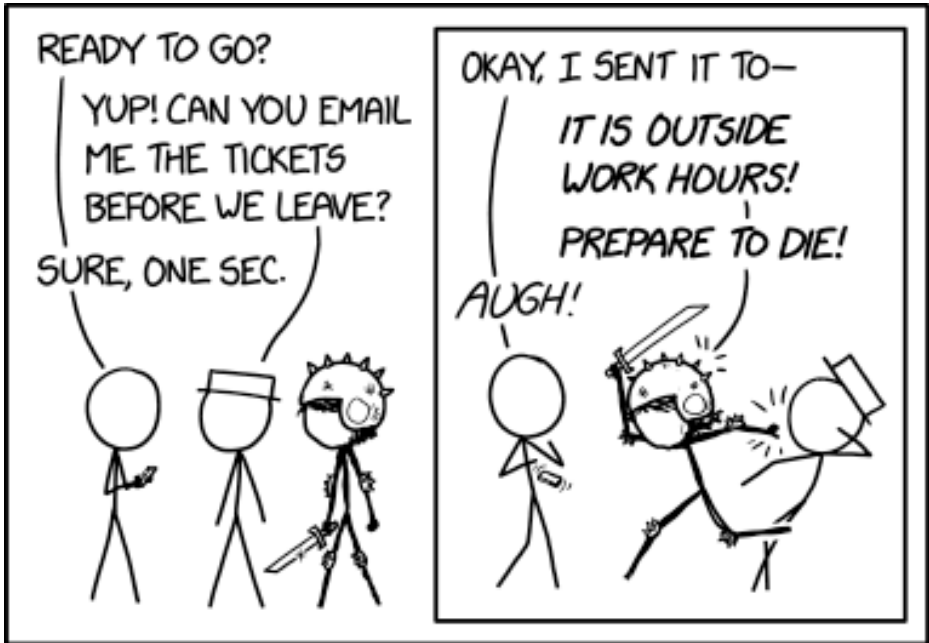
I ALWAYS FEEL BAD WHEN I TRIGGER MY FRIENDS' WORK AUTORESPONDERS.

I ADMIRE HOW YOU SET BOUNDARIES AND I HOPE YOUR COLLEAGUES RESPECT THEM! PLEASE SPARE MY LIFE!

Explanation

Cueball and White Hat are going somewhere in need of tickets (a concert, the airport, etc.), and Cueball asks White Hat if he is ready to go, who affirms this but asks for Cueball to email him the tickets before they go.

When Cueball does this he apparently opts to send them to White Hat's work email address. When White Hat is not at work, he has an autoresponder activated that tells people to not disturb him as he is not at work. Usually this means that his email server sends an automatic response telling the sender of the mail that he is not at work, and not to expect an immediate reply.

But in this comic, White Hat has a physical autoresponder standing behind him, drawn as a human with thicker/rougher lines as if clad in bulky clothing, wearing spiky knee and elbow guards and a spike-embossed and notably scarred crash-helmet upon its head. It holds a glinting, sharp sword in its hand. When Cueball inadvertently activates it, it plunges forward to 'defend' White Hat from being disturbed by work related things during his spare time. It is so aggressive that it even violently pushes White Hat out of the way, with a blow to the face so that he falls back and dislodges his hat, as it prepares to confront the perpetrator, Cueball.

In the caption below, Randall states that he feels bad when he activates his friends' autoresponders. It is

unclear if this is because he thinks he disturbs them with what they might think is work, because he then knows he will not get a reply or if he feels attacked (like Cueball in the comic) by their "aggressively worded" auto-replies.

In the title text Cueball shouts out (in all caps) to the autoresponder "I admire how you set boundaries and I hope your colleagues respect them! Please spare my life!" He therefore thinks it is a good idea to have time away from work where you cannot be contacted by your colleagues.

It is unclear if the autoresponder is a human or a robot, but the open-faced helmet reveals the fringe and neck-length hair generally seen on female characters, although for instance Megan's hair is usually longer and not so messy as this creature. This would be reminiscent of the Android series, especially 600: Android Boyfriend, where one of the androids moves past its owner. It may also be a reference to Homestuck, a webcomic which features an autoresponder as a real, living being.

#2575: What If? 2

January 31, 2022

CLARIFICATION: By 9/13, I mean September 13th, not the 9th day of Jancember, the cursed 13th month that exists between December and January in the transdimensional temporal plane.

Explanation

This comic is Randall's way of announcing and promoting his new book, What If? 2, based on his what if? blog and following his first what if book.

The entire comic (including the xkcd Header text) is a link to a what if? 2: the book page on xkcd .

Apart from promoting the book, the comic also explains why he ended up writing a sequel. After the first book came out Randall was flooded with what if? questions. Presumable mainly from his readers via e-mail, but his friends and families also started texting him with these questions. Some of these texts are displayed in the comic, but only partially, so none of the six question texts can be read. But where one might think that this would become tiresome, Randall instead tells the readers the opposite: "Honestly, I love it."

He then continues to praise the quality of the questions, mentioning no less than nine examples of what the questions were about. And in the process ensures the reader that planets, including the Earth, will be destroyed multiple times in his new book. At the end he lets the readers know that some of the features of the first book, with short answer sections and disturbing questions (likely not answered), are also included in this book.

He also states that a few of his favorites from the What If? site site have been included, so it is not all new

material. He includes his very last online What If? (Earth-Moon Fire Pole) for instance, which was released on 2018-05-21, almost four years before this comic was released. Also, by the time the book is released, it will be almost four years and four months since the last article on What If?

The final part of the comic is a picture of the book that both makes it clear when the book is released and how to preorder it.

Randall ensured the maximum possible attention to his announcement by placing a countdown in the header about three weeks prior to the announcement. This has caused a lot of speculation as to what would be revealed on the day of this comic's release 2022-01-31. The timer was inside a panel at the top right of the xkcd header text next to the standard header text: xkcd updates every Monday, Wednesday, and Friday. Inside the panel a picture began emerging after the first day, but the picture only changed approximately once every four hours. After a few weeks was it certain that it was a plane that was being revealed. And on the second to last day, around day twenty, it was clear that it featured a T. rex-like dinosaur en silhouette standing on top of the aircraft, apparently trying to eat its way into the fuselage, and it might have been possible to guess the relation to the What If? sequel. On the day before the announcement on xkcd, however, Amazon made visible a preorder page for the book, so the answer was made clear about a day before Randall had intended. This clearly annoyed users of this page as can be seen in the talk page for the

countdown.

Until then, however, there were numerous theories about the countdown and what the image would reveal as the image gradually changed throughout the eventual 136 frames.

In the title text, Randall feels that he must clarify the release day (as in 2562: Formatting Meeting), since he has often joked about the way different countries (and people) write dates. He did not use the one version he himself had promoted in earlier comics. He does however give two different versions of the release date: the first is "9/13" in the first panel, which is at least (usually — see below) only readable one way; harder to misinterpret is the more expansive "Sep 13, 2022" in the final panel. A format that he could have used to avoid any confusion is: "the book is released on 2022-09-13," using the international standard as defined in the ISO 8601 standard and shown in 1179: ISO 8601.

The clarification reads: By 9/13, I mean September 13th, not the 9th day of Jancember, the cursed 13th month that exists between December and January in the transdimensional temporal plane.

Since there are only 12 months in the year, 9/13 actually cannot be mistaken, while 9/12 might be. So there was really no need for this clarification, especially with the last text in the last panel. So this is of course just a title text joke, where he can manage to make a portmanteau of January and December ("Jancember") and then then call

this a cursed month as it would be the 13th month if it came before New Year. This comic came out at the end of January, so it could have been at the end of Jancember instead. The number thirteen is seen by many as an unlucky number, so a thirteenth month would be considered cursed by some, or at least unlucky.

In reality, a 13th month can exist in some alternate calendars and is then called "Undecimber".

At the release of this comic, the header changed to promote the website, the xkcd links in the top left section of xkcd was changed to promote the book and he made his first Blag post in more than two years with the What If 2 post.

The what if? header was also changed to accommodate promotion of the new book; not so strange, seeing as it was based on that blog. A picture is displayed at the top with the book at both ends and this text in between, with the first line taking up the top and the two other lines below, the first in a frame:

The entire picture links to the what if? 2 page.

Exactly two months after the release of this promotion comic Randall made another comic about his new what if? 2 book: 2600: Rejected Question Categories. In this he also gives the release day as 9/13, in the title text, although without any mention of the ambiguity of this date format.
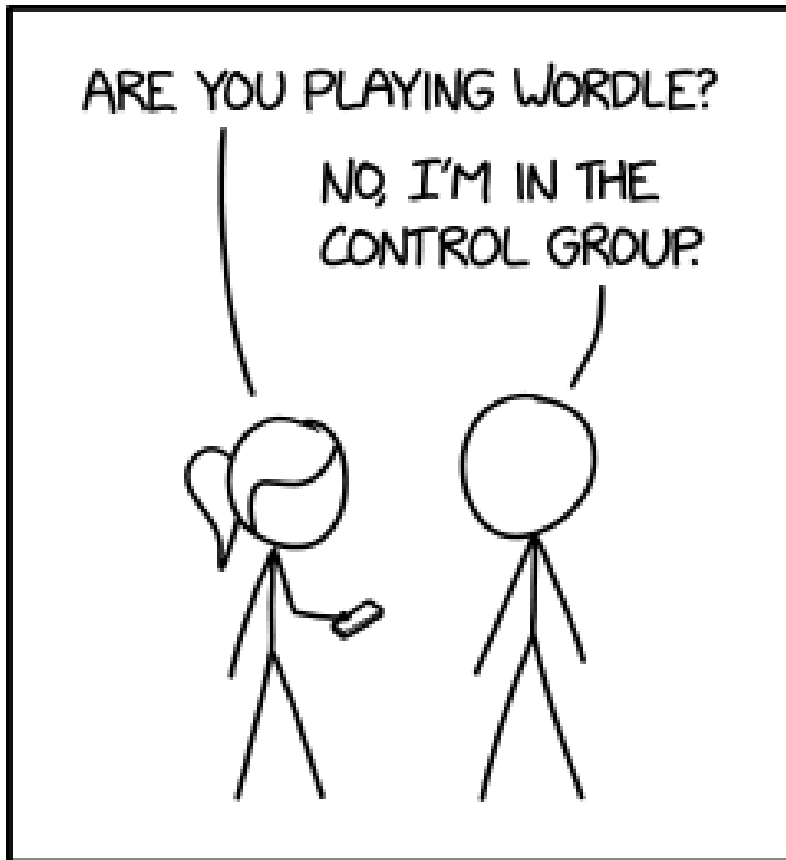
MY NEW ALL-PURPOSE EXCUSE FOR WHEN I'M NOT DOING SOMETHING

Placeble **228** x/6nnnnnn

Explanation

Wordle is a web-based word puzzle game that was especially popular when this comic was released. In the comic, Ponytail asks Cueball whether he's playing the game; Cueball replies that he isn't, because he's "in the control group". In scientific studies, the control group stands in opposition to the treatment group; whereas the treatment group receives the experimental "treatment", the control group does not, instead receiving a placebo or nothing at all. This is done to establish a baseline—what would happen without intervention—against which the result of the experimental treatment is compared later.

When Cueball replies that he's "in the control group", this implies that Ponytail and other Wordle players are part of a "treatment" group. This implies that playing Wordle may have some long-term effects worth studying.

Jokingly, this may also imply that Wordle is some sort of social experiment, perhaps a sociological study conducted by Harvard. As noted in the caption to the comic, Randall has been using this line as his new all-purpose excuse when he is not doing something. It's a clever way of saying that you're determined not to take part, as a control group requires him to avoid it. Mind control studies can also be nonconsensual experiments that massively impact public behavior.

More realistically, Cueball may be part of a real market research control group, which was not exposed to advertisements and memes supporting the game or

anything associated with the game. Market research studies have been common since the advent of advertising.

The title text is a parody of Wordle's sharing feature, which users have been posting on Twitter or other social media platforms to show their success or failure at the game. The title text shows a 5x6 grid, but calls it "Placeble" (a portmanteau of Placebo and Wordle) and has a number after it, suggesting that not only is the game a social experiment, but that a "placebo version" is being given to the control group. In the real Wordle sharing feature, the number represents the current day's game. On the date this comic was released, the Wordle website itself was on game 228, matching the number in the title text. Randall's placebo version of Wordle has blank/incorrect squares and has a score of "x/6" which is a loss in Wordle — unsuccessful after the maximum 6 tries. A potential candidate for a "Placeble" might be Absurdle, although it does not automatically end after 6 tries.

#2577: Sea Chase

February 04, 2022
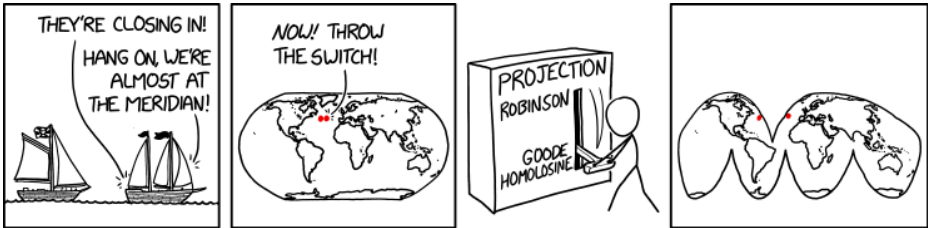
There are two rules on this ship: Never gaze back into the projection abyss, and never touch the red button labeled DYMAXION.

Explanation

In this comic, Randall returns to one of his pet subjects: map projections. Unusually, this time it is seen from the perspective of people living — or, in this case, sailing — upon the world that is quite literally being projected differently.

Two sailing ships, of circa 18th-century design, are engaged in a close chase across the Atlantic, the aggressor flying the Skull and Crossbones of a stereotypical pirate vessel. It can be seen from the flags of both ships that they are tacking into the wind, the trailing ship seeming to be lighter and yet deploying more effective canvas with two active sails than the forward one can with three. The ship being chased has a plan to escape and the means to do so. At a crucial moment, Cueball is told to flip a large incongruous switch that (like several other artifacts in the xkcd universe) alters the nature of their reality.

Whereas beforehand the world is directly represented upon a simply contiguous map, the Robinson projection, it is now changed to one (which is actually the new reality) known as the Goode homolosine projection in which the flattening of the world mitigates localized warping of angle, distance, and area by introducing discontinuities in relatively "unused" parts of the mapped world, such as the center of the Atlantic.

By precisely timing the change (as they cross a particular

meridian, possibly the 40°W one), they leave the pursuer now on the wrong side of the very real gap, allowing the pursued ship to escape whatever fate they were trying to avoid. Though there is still an oceanic connection, it requires sailing down the edge towards the tropics, rounding this particular rent in the planet's surface, and heading back up the other side. This is vastly further than Cueball's ship needs to travel to reach (presumably) any European port in which they can safely moor.

The title text elaborates on the policies of the ship: crewmates are never to look into the "projection abyss" and to never hit the red button labeled "DYMAXION."

The first rule suggests that changing the projection of physical reality produces a gap in reality — a void. This may be dangerous to gaze into or simply unnerving to crew-mates, hence the rule. This may also be a reference to a well-known quote by philosopher Friedrich Nietzsche: "He who fights with monsters must take care lest he thereby become a monster. And if you gaze for long into an abyss, the abyss gazes also into you." See Beyond Good and Evil at Project Gutenberg.

The second rule references a button that seems to do the same thing as the lever but changes the world into a Dymaxion projection. The Dymaxion map projects the Earth onto 20 triangles, which are typically chosen such that landmasses are contiguous while adding many discontinuities in the oceans. This would make navigating by ship in such a 2D world even more difficult than in the Goode homolosine projection. In

particular, crossing the Atlantic ocean becomes impossible because of the introduction of a projection abyss from Norway to the Caribbean.

The Robinson, Goode Homolosine, and Dymaxion projections have been referenced in 977: Map Projections.

A similar chase but in space, was represented in 2646: Minkowski Space. Here the pursued spaceship tried to escape by jumping to Minkowski space, and after that failed, the title text mentions jumping to Hilbert space worked. This is similar to the title text here, also mentions other modes of escaping.

#2578: Sword Pull

February 07, 2022
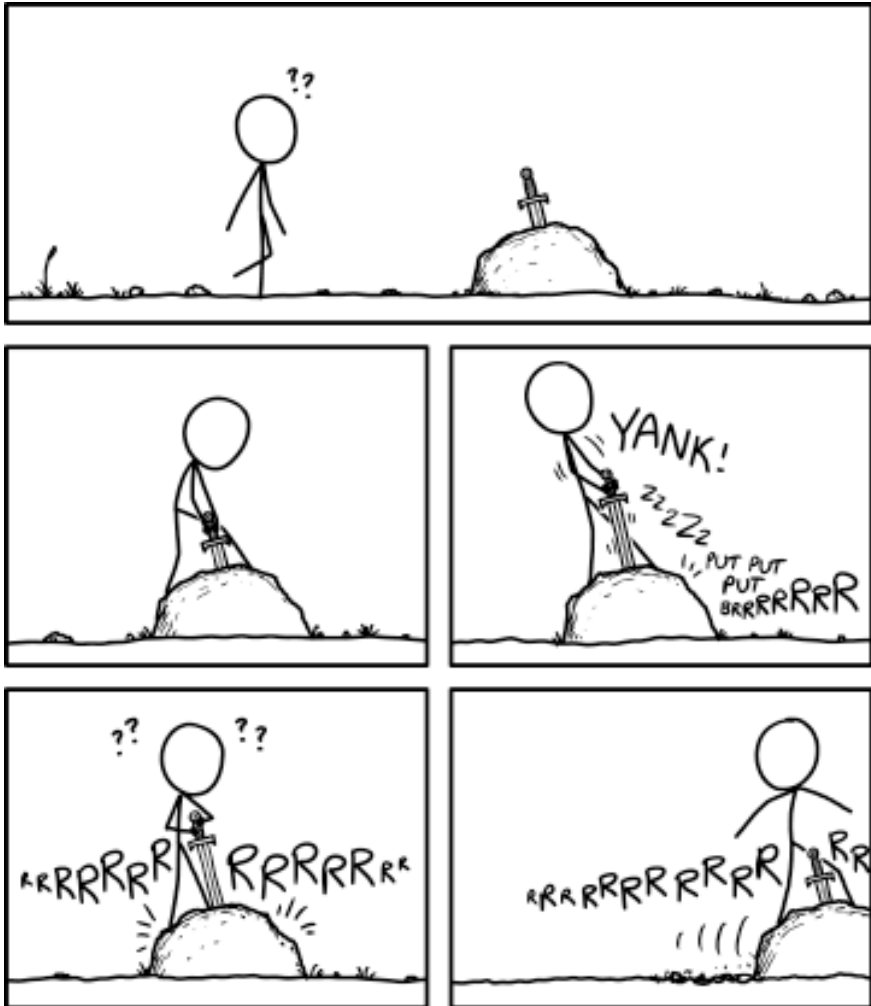
Merlin really shouldn't leave his dirt bike lying around.

Explanation

A surprised Cueball walks up to a stone where apparently a sword is stuck in almost to the hilt, embedded in a stone much like a particularly well-known fable in the legends of King Arthur. This may mean this sword is called Excalibur. Usually, the narrative is that the one who can free the significant sword becomes king of England (or, technically, Britain), see for instance Disney's The Sword in the Stone — or the scene as featured in 1521: Sword in the Stone, where Megan decides to return the sword back into the stone after reading about England on Wikipedia. (It has been commented that the one who managed to embed the sword in the stone in the first place may have had the greater skill and/or strength.)

Cueball rises to the challenge and stands atop the stone, for leverage, and pulls hard to yank it almost out of the stone. With a surprise even greater than before, he finds that the pulling of the sword merely starts a motor within the stone and, almost immediately, the whole assemblage starts moving to the right with Cueball still standing upon it. Having failed to fully remove the sword from the stone, after he releases it the sword is retracted back to its original position inside the now moving stone.
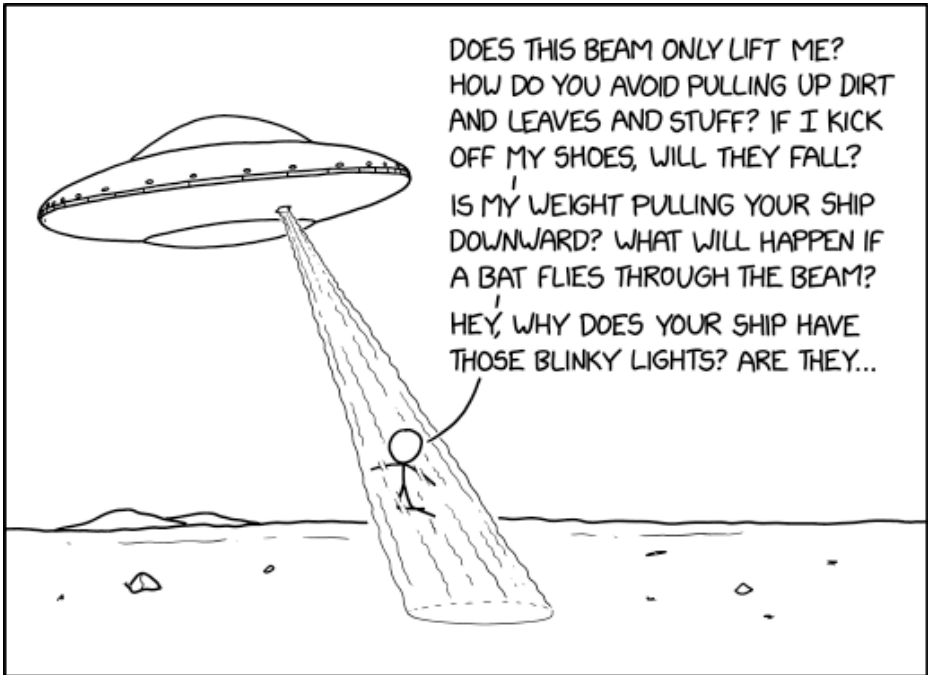
The title text implies that the sword is actually the rope starter for Merlin's dirt bike. Merlin, a wizard, is typically known as King Arthur's mystical advisor. The title text mentions that Merlin really should not just let his dirt

bike lie around, indicating that this is a common occurrence and has caused problems before. Since rocks are usually not dirt bikes in disguise,[citation needed] Randall may be describing this literally, as in a stone-bike that travels through the dirt, as it appears to represent in the last panel.

Some similarly-sized stones, namely sailing stones, do move spontaneously with up to 0.3 km/h in precise conditions. However, the stone in the comic appears to be moving at a higher speed, and sailing stones require no rope starting.[citation needed]

#2579: Tractor Beam

February 09, 2022

DOES THIS BEAM ONLY LIFT ME? HOW DO YOU AVOID PULLING UP DIRT AND LEAVES AND STUFF? IF I KICK OFF MY SHOES, WILL THEY FALL?

IS MY WEIGHT PULLING YOUR SHIP DOWNWARD? WHAT WILL HAPPEN IF A BAT FLIES THROUGH THE BEAM?

HEY, WHY DOES YOUR SHIP HAVE THOSE BLINKY LIGHTS? ARE THEY...

MOMENTS LATER, THE ALIENS SET ME BACK DOWN AND LEFT.

Did you base the saucer shape on pop culture depictions of aliens, or was that stuff based on your ships? Does the rotational symmetry help with ... hey, where are you going?

Explanation

Cueball is being pulled into a spaceship by a beam of light, called a tractor beam in the title. This is a common trope in science fiction, and usually pretty scary for the person involved. However, while Cueball is being pulled up, he asks a series of questions about the beam, about the force on the ship, and about the ship itself. The punch line is the caption - the aliens, frustrated by Cueball's continual questioning, release him and move on, to presumably find a different human to abduct and study. Many people have reported being abducted by aliens in real life, though none of these have been confirmed[citation needed]. This comic is similar to the O. Henry story The Ransom of Red Chief, in which a boy is kidnapped for ransom but ends up being so annoying to his captors that they opt to return him for free.

The first three questions deal with the properties of the beam – how it can be controlled to pull only him (and his clothes), not anything else. He also wonders whether the beam would still continue to lift his shoes if he took them off midway. Perhaps his apparel is only rising with him because it normally stays attached to him, perhaps it is similarly levitated with equal force or impulse. Theoretically, it could only lift his clothing, with enough force to hoist him along with it, though if this was done with insufficient finesse, it could cause damage to the clothing or the person. (One might be tempted to call this a Space Wedgie.) It is highly unlikely that this type of

tractor beam could be used on Cueball without him realizing it, which would likely lead to him asking how the tractor beam lifted the clothes and not him.

Next, Cueball asks if his weight is pulling the ship downward. This would be the case, for example, if he were hoisted upwards by a rope instead of the beam, as equal but opposite forces act against each other, but not if the beam alters the nature of his surroundings such as with Cavorite or another means of gravitational shielding or alteration.

Then he asks what will happen if a bat flies through the beam. Things that could happen include the beam breaking (and him falling downward) due to the projected effect being interrupted, the bat being pulled up ahead of him as it enters the effective volume of the levitating beam or else nothing at all as it is outside the actual volumetric segment of the beam that is more than ambient light-effects. It may presumably have a relationship with the same focal effect as that which avoids the ground upon which he previously stood being drawn upwards. Also, the shadow of the bat on the ground might make the light beam look like an inverted Bat-Signal.

As the ship leaves, Cueball continues asking questions, as shown in the title text. Those questions address the shape of the ship. He asks whether the aliens based the saucer shape on depictions of extraterrestrials in earth popular culture, or if classic flying saucers were inspired by them. His next question was cut off, but what we hear is, "Does
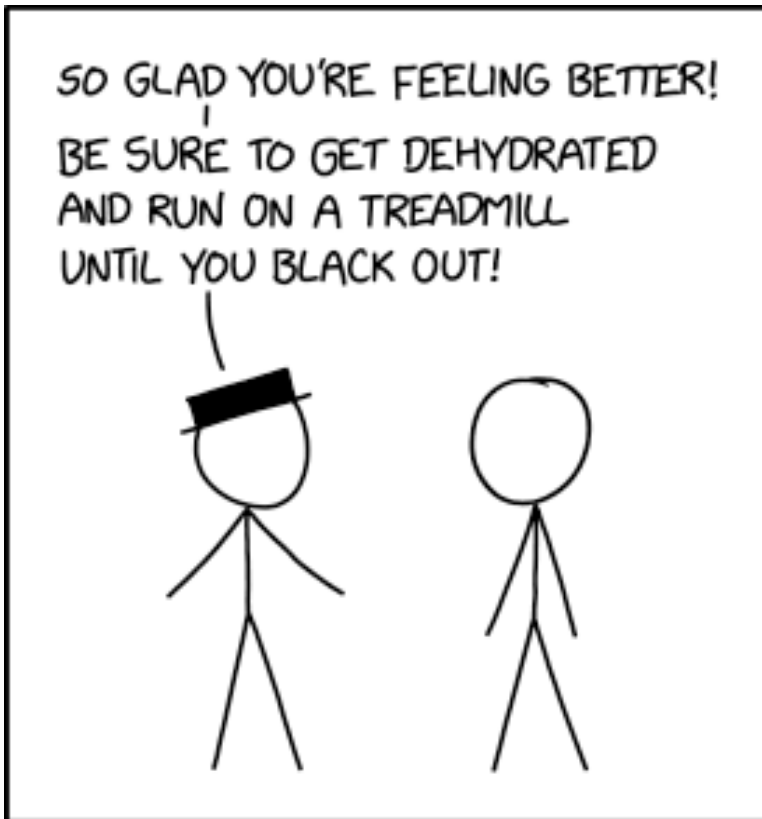
the rotational symmetry help with".

Whether Cueball actually arrived onboard the ship is uncertain. If he started badgering the aliens with questions during the lift and then (as stated) was immediately set down again then he did not. Either way, they got fed up and decided to return him to the ground instead of sharing their knowledge, or just because they preferred someone less talkative. They may prefer or expect more scared, overawed, or surprised abductees but, by whatever alien criteria they judge their catches, it seems he isn't what they want.

This was the third comic in less than three weeks featuring aliens using this type of flying saucer type spaceship. The other two comics were in a row just 6 and 7 comics before this one, 2572: Alien Observers and 2573: Alien Mission.

#2580: Rest and Fluids

February 11, 2022

SO GLAD YOU'RE FEELING BETTER! BE SURE TO GET DEHYDRATED AND RUN ON A TREADMILL UNTIL YOU BLACK OUT!

ONCE PEOPLE AREN'T SICK ANYMORE, IT'S IMPORTANT TO REMIND THEM TO STOP RESTING AND DRINKING FLUIDS.

Remember not to take it easy. Put a hot washcloth on your forehead, remain standing, and breathe dry air while taking lots of histamines. You need to give your body a chance to get sick again.

Explanation

Black Hat congratulates Cueball on his recovery from some type of illness or injury. Common advice when someone is sick is to get plenty of rest and drink lots of water, to aid recovery and to ensure they don't ignore various common causes of fluid loss.

However, being Black Hat, he targets Cueball (who has been restored to full health) to tell him that he now should do the opposite of this. While a healthy person should get a reasonable amount of exercise, and should not spend excessive time in bed, Black Hat goes to an absurd extreme. He tells Cueball to stop drinking water entirely and engage in an excessive amount of activity — in this case, by running on a treadmill to the point of physical collapse. The caption explains this, saying that it is "important" to tell people who have recently recovered from sickness to stop resting and drinking fluids, suggesting that these behaviors are for the exclusive purpose of healing and that they are useless (or even counter-productive) for someone who is now healthy.

Part of the joke may be that the most basic common and basic advice to people who are sick is good, general advice in any case. While a person who's sick should be particularly attentive to these needs, and will generally require more rest than a person who's healthy, getting adequate rest and hydration are important for maintaining health, not just recovering from illness, and pursuing the opposite would be dangerous.

The title-text expands on this backward line of thinking by suggesting to do the opposite of common remedies for various usual remedies: a hot cloth, standing, breathing parched air, taking histamines (this is as opposed to reducing fever with a cool compress, resting in bed, inhaling hot water vapors and using antihistamines). These are increasingly bizarre. A hot cloth on the forehead would range from useless to dangerous (if too hot, it could cause burns or overheating). Remaining standing isn't harmful for most people, but would soon become exhausting. Breathing dry air isn't harmful for most people, but without adequate water would dehydrate you even faster. Histamines are compounds created in the body that regulate the immune system. They're generally not available as a supplement so it would be difficult to "take" histamines. If you could somehow raise your histamine levels artificially, it could interfere with any number of bodily functions.

This comic has some resemblance to 2279: Symptoms since it also makes a joke out of symptoms or the opposite of symptoms. Although not mentioned here, this comic is probably, like Symptoms, related to the COVID-19 pandemic, as many people were still sick with it at the time of publishing this comic.

#2581: Health Stats

February 14, 2022
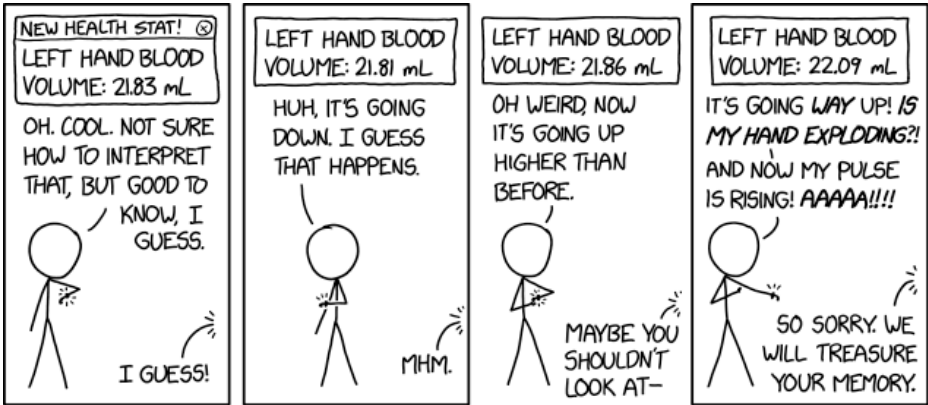
You will live on forever in our hearts, pushing a little extra blood toward our left hands now and then to give them a squeeze.

Explanation

Cueball's has a smartwatch that tells him a new health statistic. It is a new watch or a newly discovered feature.

It seems to monitor the volume of blood currently in his left hand (specifically the one the watch is being worn on the wrist of, implying it tracks the inflow and outflow and maintains a running tally) and conveys this quantity in milliliters (ml). It also tracks other stats like his pulse, as seen later, but this is not what currently interests Cueball. Instead, he studies the blood volume information and finds it changing from moment to moment. This may be from a combination of his pulse (misaligned to the frequency of the updates) or the vertical position and attitude of his hand (he subtly changes the hand's position from panel to panel). It could just be inaccuracies in the data, an issue with all scientific instruments but more so for consumer devices used without practiced expertise - it is unlikely he has strapped the measuring device tight enough onto his wrist to give scientifically consistent results, even with such slight arm movements as he makes.

He reports his thoughts on this to someone off-panel, who is heard replying to all his comments. At first, Cueball just voices the assumption that the small change is normal and accepts the movement away from a number he had no reason to disbelieve as realistic. But then two measurements in a row both increases. Although all the changes are slight, compared to the

magnitude of the numbers themselves, this freaks him out. He may be extrapolating these two data points into the future - if this rather selective trend continues, his hand may explode from its ever-increasing volume of blood. Either this, or Cueball noticed that the variation in the first three data points was ±0.025, but the final variation suddenly surpasses this level by ten times this range, massively redefining his evolving expectations.

For whatever reason he becomes anxious, a consequence of this is that his pulse also begins to rise, as also documented by the watch. This could simultaneously increase his blood pressure (not noted as being another monitored statistic) and in turn causing another rise in the volume of blood in his hand. Knowledge of the pulse increase makes him even more alarmed, which will cause a positive feedback loop at least in the short term.

The total difference between the maximum (22.09 ml) and minimum volume (21.81 ml) of blood in his hand is only 0.28 ml compared to an average of 21.9 ml, so less than 1.5% difference. This can realistically be assumed to be a normal fluctuation from heartbeat to heartbeat and/or with change of posture. For that matter, neither Cueball nor ourselves may have any idea what a normal volume of blood in his left hand would be. His comment in the first panel is that he's "not sure how to interpret" the initial measurement, and it might need rather uncommon medical knowledge to do so - even those who have learnt how much blood a typical human body should contain might be stumped by how much of that is just within a typical (or specific) human hand.

However, he seems to have assumed that 21.83 ml was a normal measurement simply since it was the first one, he saw (a stereotypical preference for early information).

Just before his anxiety reaches breaking point, his off-panel friend begins to tell him to stop looking at the watch all the time but is interrupted mid-sentence by Cueball actually freaking out. This final outbreak causes his off-screen companion to tease him by saying that "We will treasure your memory", thus joking that Cueball will soon die from the blood loss when his hand explodes.

The title text continues with this teasing where the friend jokes that after his demise he will live on forever in his friends' hearts. From there he will thus also be responsible for pushing a bit more blood into his friends' left hands, now and again, so they can feel this as a squeeze to remind them of how they lost their friend to a left-handed blood explosion.

This is likely meant to parody the tendency of people to monitor minute details of their own health, pandered to by possibly misguided developments in personal meditech, without having a clear idea of what any of the data means. This is arguably much more common today with health devices readily available, which can give the average person data about their own body but often don't offer useful context. Cueball is apparently sufficiently fixated on data that apparent changes to any metric causes him to panic. He doesn't know what the blood volume of his hand means for his health, or even whether it's a useful metric, yet he obsesses over

perceived trends in the data. The irony is that his very focus causes a more important metric (his pulse rate) to elevate. This may be intended to suggest that excessive fixation on one's own health can cause elevated anxiety. Ironically, this stress can potentially be more harmful than the things that the person has become upset about.

#2582: Data Trap

February 16, 2022

It's important to make sure your analysis destroys as much information as it produces.

Explanation

Cueball wants to analyze a "bunch" of data that he has, likely from a survey or study. Megan warns him against doing analysis because analysis produces more data — specifically, data about the data. This is implied to be a bad thing, as in, having "too much" data is undesirable — perhaps he will be expected to analyze the metadata, then analyze the metadata created by the metadata, and so on. However, data generated from analysis may provide useful insights about the original data set, e.g. finding trends or correlations between data points. Avoiding the analysis or deleting its data could deprive the analyzer of useful information. And, in the case that the analysis is flawed or impossible, there is little danger in disposing of any resulting reports.[citation needed]

The title text proposes an alternate solution: destructive analysis. It is important that the method chosen to analyze the data destroys as much information as it created, thus keeping the total amount of data constant. This expands on the concept of not having a surplus of data, suggesting that any analysis should destroy as much data as it produces. This would make data constant in quantity or in an equilibrium; of course, data doesn't actually have this limitation,[citation needed] and the user can create as much data as is needed or desired.

In the quantum world information can neither be destroyed or created; see the no-hiding theorem, for instance. Destructive analysis is a term used in

archeology; as the name implies the thing that you study is destroyed by the analysis. However, destructive analysis is rarely or never used to study data.[citation needed]

#2583: Chorded Keyboard

February 18, 2022
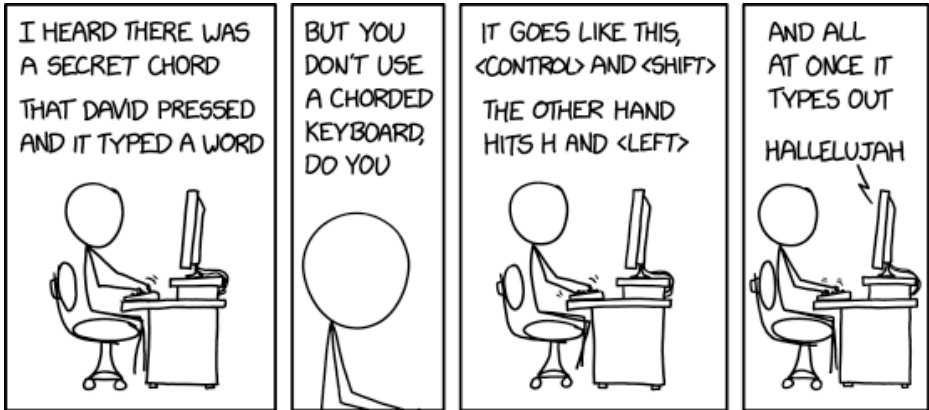
And even though it all went wrong / I'll stand before the lord of song / with nothing on my tongue but 'I don't understand, I swear I backed up my keyboard config before messing with it'

Explanation

This strip is a parody of the first verse (and in the title text, the end of the last verse) of Leonard Cohen's "Hallelujah", which has become a distinctive and popular song of which covers and versions exist. Written as a ballad, it is partly based upon the allegory of a mystical musical chord of several musical notes, that the words and tune both describe and illustrate by example.

Here is the verse from the song (see the lyrics here):

Cueball is filking upon this theme, but in his case he has somehow set up his computer so that, upon pressing a certain combination of multiple keys on his keyboard, the system will automatically type out the word "hallelujah" (xkcd's all-caps lettering makes it unclear how the word is capitalized). In his description of the process, in both the comic proper and the title text, he uses adapted lyrics that again both describe and illustrate by example. Most of the initial lyrics are floating 'thoughts'. The punchline "hallelujah", however, is 'spoken' out of his computer monitor - typical of how on-screen text is indirectly shown in this comic series. It partially continues as a song parody through the title text but then trails off into a typical computer-complaint that he perhaps may often have cause to make.

The original lyrics rely upon typically nuanced rhymes, such as "do you" (or "do ya'") with "Hallelujah", and "fifth" with "lift", but fairly reliably rhymes "chord" with

"Lord". In Randall's version, it starts with "chord" and "word" which look like they should rhyme, but would be /kɔɹd/ vs. /wɜ˞d/ in a typical US accent. Similarly "shift" and "left" might be considered not a perfect rhyme when read as prose, but should still be possible to meaningfully sing.

Technically, a chorded keyboard is one in which (nearly) all inputs are made by simultaneous pressing of a given combination of a limited number of keys, such as a literal handful of non-alphabetic keys, that the user learns to combine to represent the key-presses of more standard keyboards or (in some cases) signify entire phonemes or words. The workings of such a keyboard tends to be handled internally, sending to the computer the signal(s) that would have been sent from its larger cousin.

A big thing among Xennial hackers like Randall and his original audience was customising keyboard uses. The linux operating system was originally designed and used for personal customisation, and people move their configurations from system to system, often customising how things respond to such a degree that other users struggle to make use of their system at all. The first two major text editors, vim and emacs, were composed of different camps of how to efficiently type. The emacs camp believed it was more effective to hit many keys at once to accomplish a large task, but both editors were designed to be highly customisable. It's erroneously believed that the traditional qwerty keyboard was specifically designed to make typing inefficient so as to reduce engineering burden in making old typewriters

responsive and reliable. Given the prevalence of them, it has been common among hackers to remap a keyboard to something they may personally consider more efficient, such as to use a dvorak layout layout rather than a qwerty layout. Chorded configurations are an order of magnitude more efficient than the dvorak layout, but are more complex to configure because the result is not at all a one-to-one mapping. The traditional court reporting device is a chorded keyboard, to keep up with human speech.

Using a combination of normally single-use keys (the 'H' and a cursor) with others, including modifiers ('shift' and 'control'), i.e. 'chording' with his keyboard, is a kind of key combination found traditionally in emacs and operating system commands (such as pressing ctrl+alt+c, to copy a selection to clipboard). The ballad then comes across as an ode to system customisation and the practice of user-interface hacking, wherein a computer user knows how to rebuild their interface in almost any way they desire.

The chording example goes beyond mainstream use (shift and an alphabetic character changes the character case, whilst ctrl and a character may initiate an editing command) or mainstream multi-modifier combinations (ctrl, alt and the 'e' may result in the 'é', where the keyboard does not otherwise support it) and even goes beyond emacs-like command sequences which are generally software-specific. It seems likely that a setup such as that depicted in this comic is handled within the computer, either defined within the OS (all mainstream

desktop operating systems support alternative keyboard mapping and customisable key-combinations, often for accessibility and international keyboard support), or (as is often the case with specialist configurable gaming keyboards) via the driver installed to mediate such esoteric keyboard combinations as the user has predefined for themselves.

Cueball′s combination-keypress may in fact be better termed a ′macro′, in some contexts. The single event, somehow triggered by this particular simultaneous multi-key input, invokes the injection of a pre-specified sequence of standard characters into the appropriate text-buffer/-stream, in lieu of manual per-character input.

The title text spoofs the last verse of the (original) song, with ″Hallelujah″ being replaced by Cueball trailing off musing about having apparently lost the backup of his keyboard configuration, implying that he ended up in a position where he would want to restore said backup (for instance, having tampered with it to the point he is no longer capable of operating the keyboard efficiently, if at all).

Here is the original verse, where the title text spoofs the last three lines:

As added irony, while in the original that verse is hopeful, with the singer being thankful for experiencing joy even from a relationship that ultimately failed, contrarily in the title text Cueball is apparently expressing regret. Or,
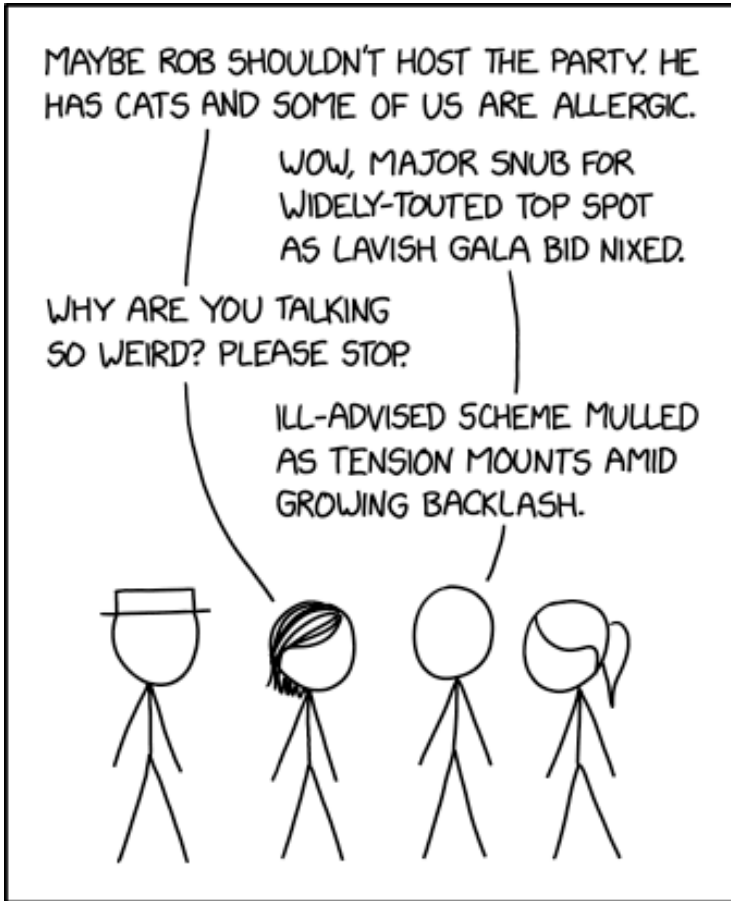
if taken literally, it could instead imply that God himself is questioning Cueball about his tampering with software, which could fit with the running gag of Cueball's (often self-inflicted) computer problems being hyperbolically atrocious.

When one modifies one's keyboard config, it can make the system seem unusable (or at least highly unexpected) to things like a boss, a spouse, or an automated maintenance system. When an error is made somewhere in the process, it can make the system seem unusable to the very person who made the changes, making it hard to change them back.

#2584: Headline Words

February 21, 2022

MAYBE ROB SHOULDN'T HOST THE PARTY. HE HAS CATS AND SOME OF US ARE ALLERGIC.

WOW, MAJOR SNUB FOR WIDELY-TOUTED TOP SPOT AS LAVISH GALA BID NIXED.

WHY ARE YOU TALKING SO WEIRD? PLEASE STOP.

ILL-ADVISED SCHEME MULLED AS TENSION MOUNTS AMID GROWING BACKLASH.

MY PROJECT TO SPEAK ONLY IN WEIRD HEADLINE WORDS DIDN'T LAST LONG.

Roundly-condemned headlinese initiative shuttered indefinitely.

Explanation

White Hat, Megan, Cueball and Ponytail are planning a party. Megan mentions that the party was planned to be at Rob's place, but that this might not be a good idea, since he has cats, and some of the participants in the party are allergic to cats. This is a valid reason. Seems likely that Megan is one of those that are allergic. Usually Rob is drawn as Cueball, but it is not necessarily Rob that is present, it could just be a discussion among some of the friends that are supposed to come to the party.

Cueball then replies to this in news-commentary fashion, using words and phraseologies that are common in headlines but rare in day-to-day use. This is strange enough to prompt Megan to ask him to stop. He continues though, although the gist of his second line is that he will stop speaking that way.

That this is indeed the case and what he is actually trying to do is explained in the comics caption. It states that Cueball's project was to speak in weird headline words. And that the project did not last for long.

News headlines are often very dramatic explanations of minor events; so are the things Cueball says here. Furthermore, some newspapers write their headlines in a stylized way which relies heavily on shorter words (such as "nixed" for "rejected"), often uses cliches (such as "tension mounts") and omits 'unnecessary' grammatical padding, a style colloquially known as Headlinese.

See below for explanation of his headlines.

The title text continues with a final headline statement from Cueball, telling everyone that the project was halted. Probably permanently.

Headlines explained[edit]

Here each of the three headlines will be explained. Several of the words used are listed in the wiki article on Headlinese.

According to the list of words: "snub" means to reject; "tout" can mean to suggest something, for approval; here, a "bid" means an attempt; and "nix" also means to put to an end/not allow to happen. The "top spot" is a venue which has status and popularity, while a "lavish gala" is an expensive/impressive festive celebration, in this case being a party.

Translating it step by step to more normal English:

Almost literal word replacement:

Trim excess words:

What he probably meant:

We can use a similar process, along with the list of words, to translate it step by step to more normal English:

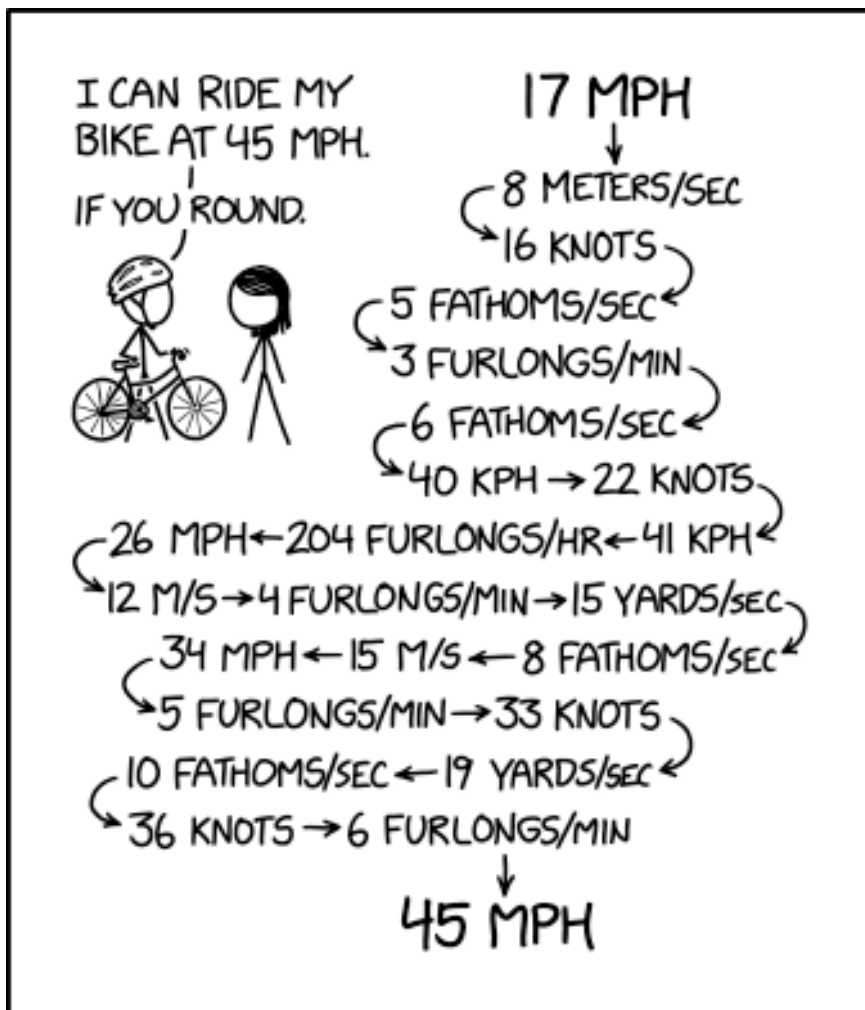Almost literal word replacement:

Apply more context and rearrange:

What he probably meant:

This time the sentence yields to relatively trivial word replacement:

What he probably meant:

I've developed a novel propulsion system powered by loss of precision in unit conversion.

Explanation

This comic is about the follies of unit conversion, later explored again in 3065: Square Units. Normally, when you say you can ride a bike at 45 mph if you round, you mean that you can ride at a speed between 44.5 and 45.5, something most people are incapable of doing.[citation needed] The joke is that Cueball actually means if you go through a extremely long chain of rounding imprecisely (see below), starting at 17 mph (which is equivalent to 27.4 km/h and not an improbable speed for an ordinary road-bike and a reasonably fit rider), you can get to the value of 45mph (72.4 km/h).

Randall also esoterically uses some more historic units here: fathoms/sec, furlongs/min, and furlongs/hr. A fathom is a unit of length, in the modern era being equivalent to six feet, usually used to measure the depth of water. Fathoms/sec could potentially be used to measure the ascent/descent speed of a submersible, but it would normally be a strange choice to enumerate the speed of a bike. A furlong is also a unit of length, equivalent to one eighth of a mile (or 660 feet or 110 fathoms) but is mostly unused except in horse racing. It is possible that furlongs/min or furlongs/hour could be used to measure the speed of a horse. Knots (nautical miles per hour) are a standard unit of measuring speed, but are typically used for measuring speed for airplanes or ships, not speed on land. However, km/h (kilometers per hour, spelled kph in the comic) is commonly used internationally to state the speed of land vehicles, while

m/s (meters per second) is a measurement encountered in scientific usage.

The title text furthers the joke by taking the imprecise rounding literally, implying that this increase could actually be used/abused as a novel form of propulsion, but it isn't clarified for what type of vehicle. It could be an engine for ground or air travel, but contains the implication that it is trying to 'trick physics' similar to the theoretical 'warp drive' conceived to propel interstellar spacecraft at otherwise impossible speeds. One interpretation of the supposed chain of conversions is that it has somehow created a great deal of energy from nothing. Suppose there existed a device or system that could magically accelerate an object from 17 mph to 45 mph without any energy input. The sped-up object could be harnessed to a generator or engine in such a way that the object was slowed back down to 17 mph, with the difference in energy being output in a useful way, and the object fed back into the device. The result would be an engine that could create both free energy and non-conserved changes in momentum.

At the demonstrated rate of about 4% median rounding gain, it would just take 73 more steps of rounding-acceleration to reach supersonic speed from the starting speed of 45 mph. If the speed of light could be approached without relativistic effects, another 349 steps would go from supersonic speed to the speed of light. (More efficient approaches may exist.)

Table of rounding[edit]

#2586: Greek Letters

February 25, 2022

WHAT GREEK LETTERS MEAN IN EQUATIONS

π THIS MATH IS EITHER VERY SIMPLE OR IMPOSSIBLE.

Δ SOMETHING HAS CHANGED.

δ SOMETHING HAS CHANGED AND IT'S A MATHEMATICIAN'S FAULT.

θ CIRCLES!

φ *ORBS*

ε NOT IMPORTANT, DON'T WORRY ABOUT IT.

υ,ν IS THAT A V OR A U? OR...OH NO, IT'S ONE OF *THOSE*.

μ THIS MATH IS COOL BUT IT'S NOT ABOUT ANYTHING THAT YOU WILL EVER SEE OR TOUCH, SO WHATEVER.

Σ THANK YOU FOR PURCHASING *ADDITION PRO®*!

Π ...AND THE *MULTIPLICATION®* EXPANSION PACK!

ζ THIS MATH WILL ONLY LEAD TO MORE MATH.

β THERE ARE JUST TOO MANY COEFFICIENTS.

α OH BOY, NOW *THIS* IS MATH ABOUT SOMETHING REAL. THIS IS MATH THAT COULD *KILL* SOMEONE.

Ω OOOH, *SOME* MATHEMATICIAN THINKS THEIR FUNCTION IS COOL AND IMPORTANT.

ω A LOT OF WORK WENT INTO THESE EQUATIONS AND YOU ARE GOING TO DIE HERE AMONG THEM.

σ SOME POOR SOUL IS TRYING TO APPLY THIS MATH TO REAL LIFE AND IT'S NOT WORKING.

ξ EITHER THIS IS TERRIFYING MATHEMATICS OR THERE WAS A HAIR ON THE SCANNED PAGE.

γ *ZOOM* PEW PEW PEW [SPACE NOISES] *ZOOOOM!*

ρ UNFORTUNATELY, THE TEST VEHICLE SUFFERED AN UNEXPECTED WING SEPARATION EVENT.

Ξ GREETINGS! WE HOPE TO LEARN A GREAT DEAL BY EXCHANGING KNOWLEDGE WITH YOUR EARTH MATHEMATICIANS.

ψ YOU HAVE ENTERED THE DOMAIN OF KING TRITON, RULER OF THE WAVES.

If you ever see someone using a capital xi in an equation, just observe them quietly to learn as much as you can before they return to their home planet.

Explanation

Mathematics uses lots of Greek letters, typically using the same letter consistently to represent a particular constant or type of variable. This comic gives a (non-)explanation of what they typically mean, see below.

In the title text the joke about capital Xi from the main comic is continued. In the main comic those using Ξ (capital xi) greets us as Earth mathematicians, indicating they are not from Earth, but have come here to learn what we know of math. In the title text the idea that any one using Ξ must be aliens is made clear. So if you ever meet someone using this letter while doing math, then learn as much as you can by quietly observing them, before they return to their home planet. Either learn from their possible advanced math (that allowed them to construct a way to get from one star system to another), or learn about them as the aliens species they represent.

Previously Randall made a similar comic, 2520: Symbols, about math symbols.

Greek letters[edit]

- π (lowercase pi): This math is either very simple or impossible. — Typically used to refer to the constant ratio between a circle's circumference and its diameter (approximately 3.14). In a common school curriculum, this constant first shows up in introductory geometry classes, which would be considered "simple" by advanced mathematicians. But often, pi can show up seemingly randomly in advanced equations that have

nothing to do with a circle at first glance, such as in infinite series. And because pi is transcendental, it can sometimes be difficult to work with pi in those situations. The comic may also be a reference to the impossibility of squaring the circle.

An alternate explanation is that the comic refers to how the symbol can sometimes be used as a variable where the 'p' sound might make sense, such as in the prime-counting function where it stands for "prime" or the Buckingham π theorem where it stands for "parameter." These uses can be confusing to students who have only ever seen a lowercase pi used for the circle constant. This has pushed college courses to use it less and less frequently for anything other than the circle constant so that now you are only likely to see π as something else in higher math. (More confusing still is the variant lowercase pi, so-called omega pi ϖ sometimes used for angular frequency instead of the more common (and very similar-looking) lowercase omega ω. In astronomy, ϖ is traditionally used to denote the longitude of perihelion.)

In a field of math known as algebraic topology, it is standard to use π to denote the homotopy groups. Despite decades of study, the homotopy groups of spheres in high dimensions are unknown.

- Δ (capital delta): Something has changed. — Typically prefixes a variable to refer to a macroscopic change in or finite difference of that variable. For instance, Δv may be the finite change in velocity v over some finite time span, while $\Delta[f](x)$ represents the forward difference of f at x, defined as $\Delta[f](x) = f(x+1) - f(x)$.
- δ (lowercase delta): Something has changed and it's a mathematician's fault. — Used in calculus. In many areas of

math, systems are studied by introducing small changes (perturbations) in input variables and observing how the system changes. The perturbations introduced are often written down as x → x + δx for some variable x being perturbed, where δx is the change being introduced. These are often applied in physics (perturbation theory, the principle of least action, Noether's theorem,...). Since this change was purposefully introduced by the mathematician instead of occurring naturally, it is, therefore, their fault.

- θ (lowercase theta): Circles! — Used in trigonometry. Typically used to refer to an angle, and is notably used in the polar coordinate system. The text refers to its close relationship with circles, on which the polar coordinate system is based. In European handwriting, the variant form ϑ is commonly used with the same meaning.

- ϕ (lowercase phi): O R B S — Typically used to refer to another angle other than one referred to by theta. It's used in spherical coordinates, and the text refers to how spheres, or orbs, are important in spherical coordinates. Lowercase phi has two forms in modern typography which are confused by this website's default font. In the comic, it has a complete circle with a vertical line passing through it, which is what Knuth called "phi." The alternate form, φ, is what Knuth called "variant phi" and can be written in a single stroke. Most fonts reverse the way these symbols are rendered. There is no difference in meaning between the symbols. Additionally, "O R B S" is written with spaces between each letter, possibly a reference to the linguistic phenomena of surreal memes and their tendency to add spaces between letters of "surreal-sounding" words like "orbs".

- (lowercase epsilon): Not important, don't worry about it. —

Typically used to refer to a very small quantity. may be an error term in a statistical model (which is usually small if the model is useful), a remainder term in an approximation (same), or an arbitrarily small (positive) quantity in analysis. Although a total cumulative change of "" is negligible, in analysis, is most often applied in a context of an infinitesimal change occurring with infinite frequency. The study of ratios of quantities that approach zero gives rise to infinitesimal calculus. This Greek lowercase letter has two common modern variants, and ε. is called the "lunate epsilon" and may be more common in the U.S. A stylized version () is used as the mathematical symbol for "is an element of." ε is what Knuth called the "variant epsilon" and is never used for the "element of" symbol but otherwise has identical meaning. Because epsilon represents an arbitrarily small (positive) quantity, there's no reason for anyone to worry about it from a practical standpoint.

- υ,ν (lowercase upsilon and nu): Is that a v or a u? Or...oh no, it's one of those. — Common in college-level physics and engineering equations. ν commonly represents wavenumber in physics as well as a wide variety of other variables, often with names starting in N (e.g. neutrino) or V (e.g. viscosity). Lowercase upsilon is rarely used, probably to avoid confusion. The symbols look remarkably similar to Latin u and v, to the point that they are nearly indistinguishable in some fonts; Randall has complained about this before in 2351: Standard Model Changes. The use of both terms together is most commonly seen when performing integration by parts, a famously counterintuitive method of integration (one of those).

- μ (lowercase mu): This math is cool but it's not about anything that you will ever see or touch, so whatever. — Used broadly in

the abstract mathematical fields of category theory and measure theory. Also used in statistics for the mean (average). Physicists use Latin letters for the indices of the 3-vectors of classical physics and Greek indices, including µ, for the 4-vectors of special relativity. This leads to µ being ubiquitous in a field that is very far from everyday experience (where speeds approach the speed of light). It is also employed in statistics for the population mean, which is a quantity that the statistician never actually knows and frequently wants to estimate. Equations requiring a µ are thus impossible to apply directly. However, µ is used in physics for the coefficient of friction in the Coulomb model, typically used to approximate resistive forces between dry solids of different materials sliding past each other. A very common use of µ in science and engineering is as the symbol of the SI prefix micro- for a millionth. Unicode has officially added a point for µ as the "micro sign," distinct from its usual codepoint as the lowercase Greek letter mu.

- Σ (capital sigma): Thank you for purchasing Addition Pro®! — Typically used as a symbol for the sum of a series of numbers. The comic is making fun of summation, pointing out that it's essentially a complicated, "pro" version of simple addition. The capital sigma is often used as the icon for the all-important "sum" button in spreadsheet software. However, the sigma operator is often necessary for explicitly defining infinite sums, avoiding ambiguous notation like an ellipsis (...).

- Π (capital pi): ...and the Multiplication® expansion pack! — Typically used as a symbol for the product of a sequence of numbers. The joke is the same as for summation. Here, it is advertised as an "expansion pack," a term used for a piece of software that cannot stand alone but adds features to some

existing software. Any paid spreadsheet or database program should already have the ability to perform multiplication. The ® symbol indicates that Multiplication is a registered trademark somewhere, which is unlikely, as the term is not unique. However, common words are registered as parts of longer trademarks rather often.

- ζ (lowercase zeta): This math will only lead to more math. — Frequently used for the Riemann zeta function in analytic number theory, a function of complex numbers which is challenging even to define and which is the focus of a famously unsolved problem in highly advanced mathematics. Zeta is used much less often in other contexts, such as the ζ-potential in colloidal chemistry, and even there it is likely to just lead to more math.

- β (lowercase beta): There are just too many coefficients. — This could be a reference to the typical usage of beta to represent coefficients of independent variables in the ordinary least squares regression model. Regression can potentially have a large number of independent variables, hence potentially many different betas (differentiated by a subscript, or compacted into matrix notation) would be used, while there is only ever a single zeroth-order coefficient α in these models. Alternatively, the comic might suggest whatever source this equation is from has run out of Latin letters to use as symbols, and is now going through the Greek letters.

- α (lowercase alpha): Oh boy, now this is math about something real. This is math that could kill someone. — As the first Greek letter, α is used for a tremendous variety of purposes in math. For example, it is used to represent the probability of a Type-I error (false positive) occurring in a hypothesis test. It could also

possibly refer to the fine-structure constant which shows up in high energy physics, atomic physics, quantum electrodynamics, and at least one other xkcd comic. Alpha could also refer to angular acceleration, and a rapidly-rotating system is capable of killing people in a number of interesting ways. In aviation, α refers to angle of attack, which could cause a deadly aerodynamic stall if it gets too large. Another dangerous meaning for α comes from ionizing α-radiation: While it can be easily blocked by even a sheet of paper, it has been used for assassinations through ingestion.

- Ω (capital omega): Oooh, some mathematician thinks their function is cool and important. — The last letter of the Greek alphabet and thus often seen as momentous (the end, the final word, death). The capital letter has been used as the symbol for a variety of mathematical functions, the first uncountable ordinal, and Absolute Infinity. It is commonly used in physics and electrical engineering as the symbol for ohms, a unit for electrical resistance. Capital omega has produced a fascination in common culture, perhaps due to God reportedly describing himself as "the alpha and the omega" in the Book of Revelation or due to its highly distinctive shape. It is often used to represent something of grave or transcendent significance. So using it to name your function (instead of a conventional symbol like f or g) may mean you think the function is particularly important.

- ω (lowercase omega): A lot of work went into these equations and you are going to die here among them. — Used for the least transfinite number of ordinals, the order type of the natural numbers under '<'. The line about dying here among the transfinite equations may be in reference to the "eternity" of the infinite set it represents. It is also used in physics and electrical

engineering for angular frequency, equal to 2π times the frequency, and thus it is ubiquitous in equations dealing with all sorts of wave phenomena. ω is also used for the angular velocity of a rotating system, defined by $v = r \times \omega$.

- σ (lowercase sigma): Some poor soul is trying to apply this math to real life and it's not working. — In statistics, σ commonly refers to the population standard deviation of a distribution. Many simplified statistical equations substitute the population standard deviation σ for the sample standard deviation s for simplicity, even when this is not justifiable. A common example is using the normal distribution to model the mean of several identically normally distributed variables instead of the T distribution. The variant ς is used at the end of Greek words (called the "final sigma") but is rarely used in math or science.

- ξ (lowercase xi): Either this is terrifying mathematics or there was a hair on the scanned page. — Randall comments that this looks like a strand of curly hair. Xi is used in the Riemann Xi function and sometimes as a variable or function symbol in higher math. It is famously difficult to write in a way that is consistent and clearly distinct from other symbols.

- γ (lowercase gamma): Zoom pew pew pew [space noises] zoooom! — Lowercase gamma is used for the Lorentz factor, an important variable in special relativity calculations. Its use implies that you are dealing with speeds approaching the speed of light and therefore with spaceships or other moving objects not confined to Earth. γ-rays are also the highest energy photons, so a space opera might have ships flying near the speed of light firing gamma-ray weapons that go PEW PEW. γ is also used as the symbol for the Euler-Mascheroni constant and occasionally as a variable or function name.

- ρ (lowercase rho): Unfortunately, the test vehicle suffered an unexpected wing separation event. — Used in statistics to measure the association between variables. Lowercase rho often represents volumetric mass density, such as the density of air that a wing might be traveling through. The density of a fluid is directly proportional to the Reynold's number, which dictates the sort of physics used to model motion through the fluid. Flying a plane in conditions with a Reynold's number well outside of what it was designed for could have catastrophic consequences. A variant symbol ϱ with the same meaning is common in European handwriting.

- Ξ (capital xi): Greetings! We hope to learn a great deal by exchanging knowledge with your Earth mathematicians. — Probably the least used Greek letter in math and physics despite being easy to write and recognize. According to the comic, anyone using this letter is likely a being from another planet. It does see very occasional use, such as in the Riemann xi function or as the symbol for a class of heavy baryons in particle physics. It resembles but is not to be confused with a "hamburger button" or a triple equals sign . Coincidentally, it also resembles the Chinese or Japanese character for the number 3 (). Randall thinks it most closely resembles alien writing.

- ψ (lowercase psi): You have entered the domain of King Triton, ruler of the waves. — Both capital and lowercase psi are shaped like tridents. In classical mythology, Triton is one of the gods of the sea, alongside his father Poseidon, and tridents are commonly associated with sea gods. In quantum mechanics, either psi is used to represent the wave function of a particle, leading to a pun. (Psi is also used in mathematics to represent the sum of the inverse of the Fibonacci numbers, the division

polynomials, the supergolden ratio, and other purposes.)

#2587: For the Sake of Simplicity

February 28, 2022

YOU MAY ASSIGN EACH GARDENER'S TOKEN TO A SECONDARY GARDEN PLOT WITHIN A 30-MINUTE WALK FROM THEIR HOME PLOT.

FOR THE SAKE OF SIMPLICITY, EACH GARDENER IS ASSUMED TO HAVE A CONSTANT WALKING SPEED PROPORTIONAL TO THEIR HEIGHT AND CARDIO SCORE.

FOR THE SAKE OF SIMPLICITY, CARDIO SCORES ARE INHERITED MATRILINEALLY...

IF YOU'RE WORRIED THAT YOU'RE MAKING SOMETHING TOO COMPLICATED, JUST ADD "FOR THE SAKE OF SIMPLICITY" NOW AND THEN AS A REMINDER THAT IT COULD ALWAYS BE WORSE.

For the sake of simplicity, gardeners are assumed to move through Euclidean space--neglecting the distortion from general relativity--unless they are in the vicinity of a Schwarzschild Orchid.

Explanation

Cueball appears to be explaining a gardening-related board game to Ponytail and White Hat. As he describes the game mechanics he states that many things have been made more convenient "for the sake of simplicity" — but as his mechanics are revealed to be incredibly complex after simplification, the refrain "for the sake of simplicity" instead comes across as a warning that the rules could be even more complicated.

It's shown pretty quickly that Cueball's mechanics are needlessly intricate, and his definition of "simplicity" is not nearly simple enough: the lore of the game says gardeners may tend to secondary plots no more than "a 30-minute walk from their home plot", but where most games would simply state an arbitrary number of tiles a gardener token may walk, Cueball expects his players to calculate how far an adult human actually walks in 1800 seconds. This immediately spirals into the game tracking far more variables than necessary such as height and "cardio score", or even things like the curvature of spacetime in the area, and the direct inheritance of a single "cardio score" which requires tracking the gardener's matrilineal line — instead of factors more typical to games such as weather or terrain.

Features of Cueball's game include:

• Tokens to represent competing gardeners
• Plots for the players to garden, both home plots and

secondary garden plots

- Mechanics to assign speed of transit between plots
- Gardener attributes, including height and cardio scores
- Hereditary trees to determine gardener attributes according to the gardener's ancestry - matrilineally refers to inheritance from the mother's side
- Euclidean and non-euclidean space, in accordance with the theory of general relativity.
- The presence of particular species of flora that can warp space-time

As gardening is itself an oddly mundane premise for a board game,[citation needed] it is entirely possible that gardening is just a minor element of a much broader game.
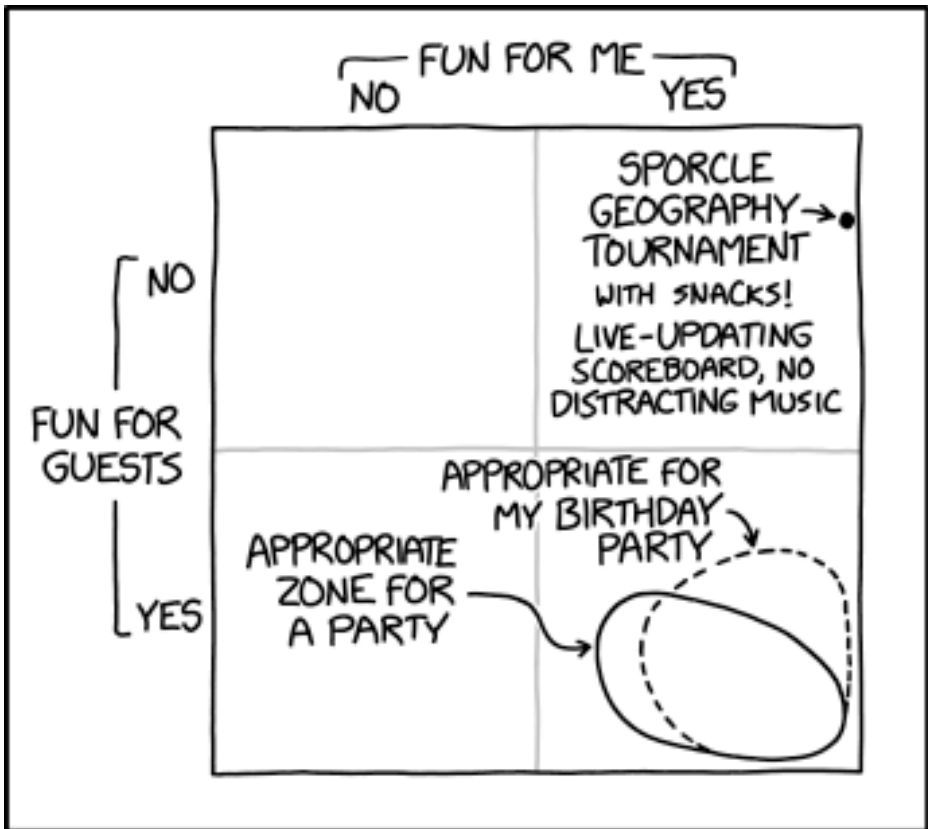
The title text mentions that the space is assumed to be Euclidean, which is what most people would assume since it corresponds to our normal experience, so this is not something that normally needs to be explained. But then it says that this isn't true in the vicinity of a Schwarzschild Orchid. An orchid is a type of flowering plant, which is relevant to a gardening game, but Schwarzschild refers to Karl Schwarzschild, a physicist who solved equations related to general relativity; the Schwarzschild radius is the boundary of a black hole, and spacetime is severely warped in this vicinity, so Euclidean geometry and Newton's Laws don't describe motion here well. Most boardgames that even care about Euclidean principles only apply them to the 2D planar

playing-surface, it seems possible that Cueball has already accounted for the slight (but non-zero) effects of the curvature of the Earth and/or changes in elevation across the apparently detailed simulation within the game environment, through 3D Euclidean space. And, further, the title text implies he actually sat down to calculate the distortion of general relativity upon the walking speed of an adult human, then later used these equations for an entire game mechanic — albeit one that players can mercifully skip when there are no gardeners in proximity of Schwarzschild Orchids.

The next comic 2588: Party Quadrants, also mentions complicated rules for scoring a contest. This seems somewhat related to the complicated rules of this game.

#2588: Party Quadrants

March 02, 2022

FUN FOR ME — NO ... YES

FUN FOR GUESTS — NO ... YES

SPORCLE GEOGRAPHY → ● TOURNAMENT WITH SNACKS! LIVE-UPDATING SCOREBOARD, NO DISTRACTING MUSIC

APPROPRIATE FOR MY BIRTHDAY PARTY

APPROPRIATE ZONE FOR A PARTY

I KEEP ACCIDENTALLY PLANNING PARTIES IN THE TOP RIGHT QUADRANT.

Single-elimination might provide more drama, but I think we can all agree that a comprehensive numerical scoring system will let us better judge the party's winner.

Explanation

In this comic there is a graph divided into quadrants to visualize the range of possibilities of fun for Randall and for guests at parties hosted by Randall. The top and bottom halves are labeled as "fun for guests" with "no" in the top quadrant and "yes" in the bottom quadrant. The left and right halves labeled as "fun for me", i.e. fun for the host Randall, with "no" in the left quadrant and "yes" in the right quadrant.

In the bottom right quadrant (which indicates fun for everyone), are two separately outlined but largely overlapping regions, like a Venn diagram. One is the appropriate zone for a party (in general) and the other other applies to Randall's own birthday party. They are both vaguely ellipsoid and both enclose a reasonable to nearly maximal amount of fun in both dimensions. The range for the birthday party is skewed towards being marginally more for Randall's enjoyment, but is still firmly in the bottom right quadrant, showing the party planner still gives consideration for the guests to feel welcome and happy.

Omitting the extreme edges may indicate that there are no points there because it's impossible to completely please everybody, or it may be a warning that a party should not be such extreme fun that it gets out of hand nor let the balance of fun stray too far from equal. There are no specific points labeled in this quadrant.

The top right quadrant is meant to represent ideas that Randall and precisely nobody else would find fun. He gives an example, reportedly his latest idea for a party, is in the upper right quadrant, labeled "Sporcle geography tournament with snacks! Live-updating scoreboard, no distracting music". From a cursory glance of this label it should be evident to Randall's fans and associates why he would enjoy this party, and evident to everyone why this would be extremely boring to the vast majority of people who aren't Randall.

The elements of Randall's "fun" party include:

In the caption, it is mentioned that for some reason, Randall keeps "accidentally" planning parties in the top right quadrant (fun for him, not for guests). Presumably, he is so caught up in what he considers entertaining that he doesn't take into account the interest level of the guests. This is regardless of which party-context, and well outside either of the appropriate zones. This diagram though indicates that he know this is the case, but maybe he is first able to place the point on the diagram after the party, when he realizes that his guest leaves early (again) out of boredom.

The title text elaborates on the Sporcle trivia game night that Randall has planned in the upper right quadrant. It makes mention of a comprehensive, and perhaps overly complicated, scoring system to determine who is the party's winner. That he's talking about "winning the party" suggests he is fundamentally misunderstanding the point of parties -- they're supposed to be fun for

everyone attending, not (exclusively) a competition.

See the previous comic 2587: For the Sake of Simplicity, which seems to be a bit related to what Randall thinks is fun, whereas other might not.

#2589: Outlet Denier

March 04, 2022

CURSED CONNECTORS #78
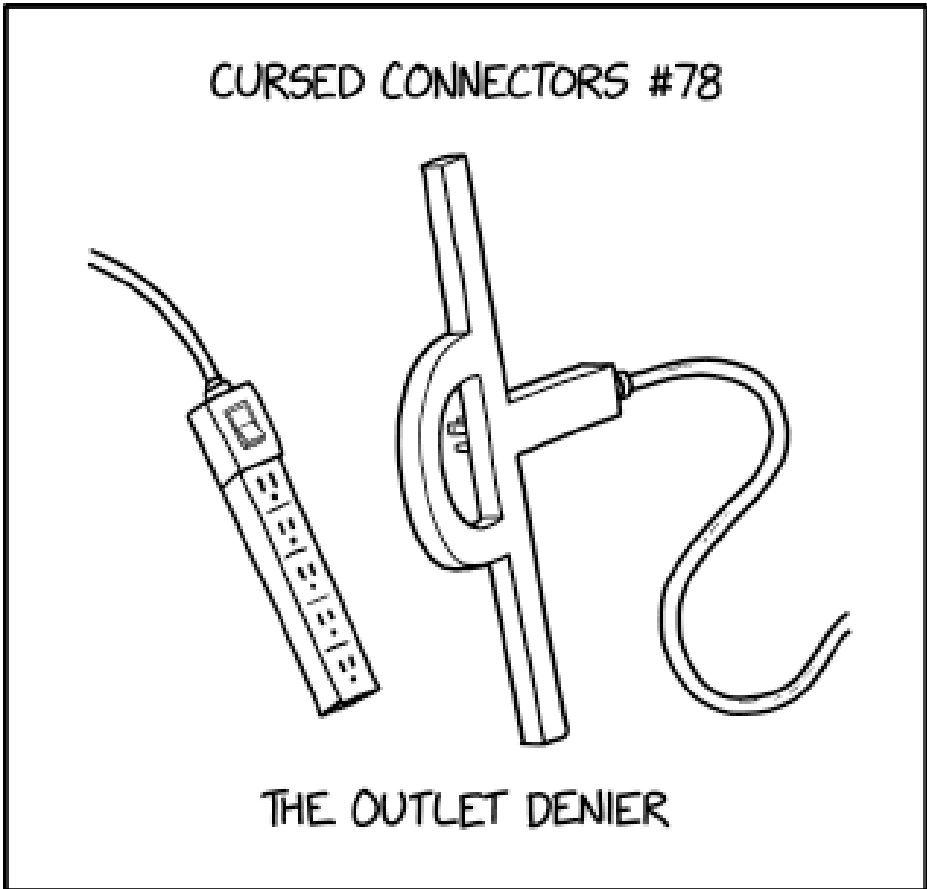
THE OUTLET DENIER

There are regularly placed bumps on the underside just the right size to press the rocker switch on the power strip.

Explanation

This is the fifth installment in the series of Cursed Connectors and presents Cursed Connectors #78: The Outlet Denier. It follows 2507: USV-C (#280) after about half a year and was followed about 4 months later by 2642: Meta-Alternating Current (#120).

The outlet denier connector in this comic is the large connector to the right. It has a plug on the downward side that is supposed to go into a power strip or other type of outlet. It has two long bars extending up and down off the plug, as well as a D shape on one side with another, slightly less long bar on the other side of the D, that has the cord connected to it. The purpose of the outlet denier is to block access to as many other ports on a power strip as possible, hence the name. It is designed to work with many different types of power strips, such as the standard one displayed in the comic, as well as ones with the sockets rotated 90 degrees (the long bar extending to the cord) and other types of outlets like the triple outlet on the end of many extension cords and two dimensional power strips that extend a couple of outlets left and right as well as up and down (the D shape on the side). The extreme bars to each side may also prevent plugging the Denier into an outlet close to the floor, forcing the user to use a power strip or similar item for it.

There is an example power strip displayed to the left of the outlet denier, used to help explain that the outlet denier is designed to block as many other sockets on a

power strip as possible. The power strip is presumably of the type with a rocker switch that can turn the entire power bar off. This power bar has five outlets.

Many appliances require transformers or other large components on their power cord. Sometimes these "power bricks" are built around the plug. The comic is making fun of these types of power bricks, as they often block access to other sockets on a power strip or wall outlet. This can be really annoying when you want to plug in many different appliances into a power strip.

Other plugs are deliberately designed to block the other half of a duplex outlet, preventing users from plugging anything else in that could overload the circuit.[actual citation needed] The comic could be depicting an extreme case of a cumbersome connector shape designed to block an entire power strip, as the appliance connected to it uses so much power that a single extra item plugged into the power strip would cause problems.
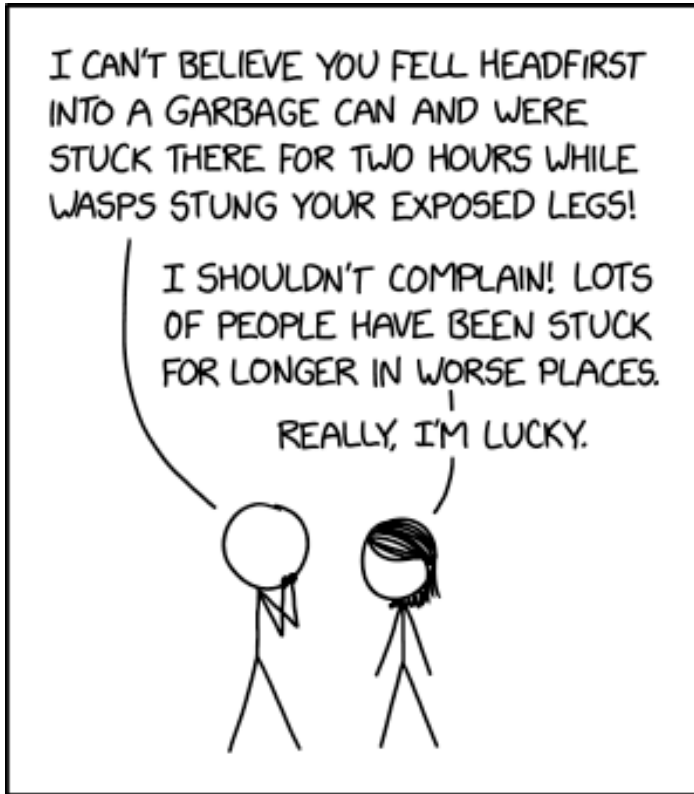
The title text says that the outlet denier has bumps on the underside of the long bar that would match up with the location of the rocker switch no matter which outlet of the strip it is plugged into. It's not clear whether this will turn the power switch off or force it always on. But either way, it gets in the way of the user being able to control the power themselves.

If it forces it off, then the Outlet Denier cannot even be used. So to at least assume someone might actually use it, it must force it on. Since there is nothing else that can go

into the power strip, it is not that important whether it is possible to switch it off though.

#2590: I Shouldn't Complain

March 07, 2022

I CAN'T BELIEVE YOU FELL HEADFIRST INTO A GARBAGE CAN AND WERE STUCK THERE FOR TWO HOURS WHILE WASPS STUNG YOUR EXPOSED LEGS!

I SHOULDN'T COMPLAIN! LOTS OF PEOPLE HAVE BEEN STUCK FOR LONGER IN WORSE PLACES. REALLY, I'M LUCKY.

THE MORE UNPLEASANT SOMEONE'S EXPERIENCE IS, THE MORE THEY APOLOGIZE FOR COMPLAINING BECAUSE IT COULD BE WORSE.

Bald-faced hornets are only a **2** on the Schmidt pain index, so I shouldn't complain. The tennis ball ejected from the dryer exhaust vent could have ricocheted off the nest of a much higher-scoring insect before knocking me off the

ladder. Really, I'm lucky.

Explanation

Megan has had a very unfortunate experience of falling into a garbage can and being repeatedly stung by wasps. Cueball expresses an appropriate amount of horror about it. However, Megan seeks to downplay this experience by saying "I shouldn't complain" and that she's "lucky" it wasn't worse. This has become a habit in Western culture, like comparing minor issues to "kids starving in Africa" or war-torn countries, notably Ukraine (this comic was published during the Russian invasion of Ukraine starting in February 2022 and was ongoing when this comic came out on March 7).

Humans have a tendency to re-calibrate their mental scales to place their actual experience in the center. Cueball, who has never experienced being trapped for hours with stinging insects, rates this in comparison to not being trapped at all. Megan, however, rates it in comparison to other uncomfortable places a person could be stuck.

The title text explains how Megan came into such a mess. A tennis ball used in a clothes dryer got stuck in the exhaust vent, and was shot out of the house through the exhaust vents hole in the wall. Then it hit the wasp nest and ricocheted over on Megan knocking her off the ladder she was standing on. Since she was close to the nest, she may actually have been up on the ladder in order to see if she could remove the nest. The fall from the ladder made her end up in the trash can where she

could not get out. The angry wasps began stinging her legs. This continued for two hours.

In the title text, Megan continues to downplay her experience even though it was very painful. She says that the wasp nest was of the type bald-faced hornets.

The Schmidt sting pain index is a scale developed by entomologist Justin O. Schmidt to rank the relative pain caused by different stinging insects. This scale ranges from 0 (for stings that are completely ineffective) to 4, which denotes torturous and nearly incapacitating pain (originally, Schmidt only classed one species as a 4, but two additional species have since been added at this level). Megan says her stings were a 2 on the scale, which denotes "familiar" pain, comparable to that of the common Western Honey Bee. Most people would find that experience incredibly painful, particularly since she endured multiple stings over a long period of time, but Megan points out that there exist insects with more painful stings.

Megan concludes that she'd been lucky, based on the argument that she theoretically could have endured something worse than she did. The joke, of course, is that by almost any subjective standard, her experience was deeply unlucky.

She also further downplays the situation by focusing attention on the sting pain index instead of the sting lethal capacity, described by the author of the pain index. The two are not necessarily equivalent. Let's assume that

all insects in the colony affected stung Megan at least once over her two hour ordeal. A colony capable of sustaining an attack over two hours would probably be at least as large as the typical maximum size for a bald-faced hornet nest. Such an attack might (depending on number of attackers and the species of wasp) deliver enough venom to kill 84 kg (185 pounds) worth of mice (or human?). Given such an attack, Megan would probably not be standing around in routine conversation, casually discussing the incident. She would far more likely be in a hospital bed, and in a gruesome fight for her life.

Qua qua qua is the sine qua non of sine qua non qua sine qua non.

Explanation

Qua is a relatively rare, formal word, from Latin, roughly meaning "in the capacity of". For instance "In essence, military regimes are autocracies in which the military qua organization performs many of the functions performed by the ruling party in single-party regimes".

Saying something is "X qua X" (e.g. "entertainment qua entertainment") means when X is being viewed in its most typical capacity (eg, entertainment as something that entertains, rather than as a business, a form of propaganda, or whatever).

For example, "A copy, qua copy, can never be the equal of the exemplar, and it may be much its inferior."

Cueball claims that people only use qua to "sound pretentious" without properly understanding its meaning. Thus, people do not use "qua qua qua", or "qua for the sake of qua". However, Megan one-ups this with a series of seven quas: she compliments Cueball's successful use of "qua qua qua qua qua qua qua", or "the phrase 'qua qua qua' for its correct meaning".

The joke is that, for the reader, the conversation has likely dissolved into gibberish because of unfamiliar terminology and semantic satiation. This is similar to other complex sentences such as "Buffalo buffalo Buffalo buffalo buffalo buffalo Buffalo buffalo", "That that is is that that is not is not is that it it is", and "James while

John had had had had had had had had had had had a better effect on the teacher". Following this trend, you can create a grammatically correct sentence that includes 'qua' a consecutive number of times equal to (2n-1), where n is a natural number.

The title text goes further with this, using a Latin phrase sine qua non (meaning literally "without which not"), commonly rendered as "that which is absolutely necessary" or "essential". Thus, the title text says that "the word 'qua' in its real meaning is essential to the phrase 'sine qua non' used correctly".

However, the "qua" in "sine qua non" is a demonstrative pronoun ("which"), unlike the other "qua" which is an adverb, so the similarity is only coincidental.

There are two types of dichotomy: False dichotomies, true dichotomies, and surprise trichotomies.

Explanation

A dichotomy is two alternatives which are normally mutually exclusive (such as the dichotomy between a flat Earth and non-flat Earth). A false dichotomy is a logical fallacy based on an incorrect perception of limited options (for example: if the page background isn't white, it is black).

Cueball has apparently made one such error and is being called out by White Hat for it. Upon having this pointed out to him, Cueball says that we must embrace false dichotomies, because the only other option is cannibalism. This statement is another false dichotomy, as presenting false dichotomies is not the only alternative to cannibalism.[citation needed] The reverse (that cannibalism is incompatible with expressing false dichotomies) is also not potentially true, as eating people may eventually result in having nobody you need to present false dichotomies to.

Cueball has thus created another false dichotomy to excuse his first, at which referring to cannibalism is most likely a non-sequitur argument.

The title text states that there are two kinds of dichotomies, making a dichotomy in itself. Due to three types of dichotomy being mentioned, and only two being foreshadowed, this statement is itself a surprise trichotomy, or three-parted choice. The title text is a variation of the "Two kinds of People" joke. The classic

math nerd variant is "There are three kinds of people in the world, those who can count, and those who can't." Alternatively, it may refer to a variation about binary. The original joke usually goes something like this: "There are 10 types of people: those who know binary, and those who don't." The variation is usually something like the following: "There are 10 types of people: those who know binary, and those who don't, and those who weren't expecting a ternary joke." Another version of this kind of joke is "there are two kinds of people: those who can extrapolate from an incomplete data set,"

#2593: Deviled Eggs

March 14, 2022
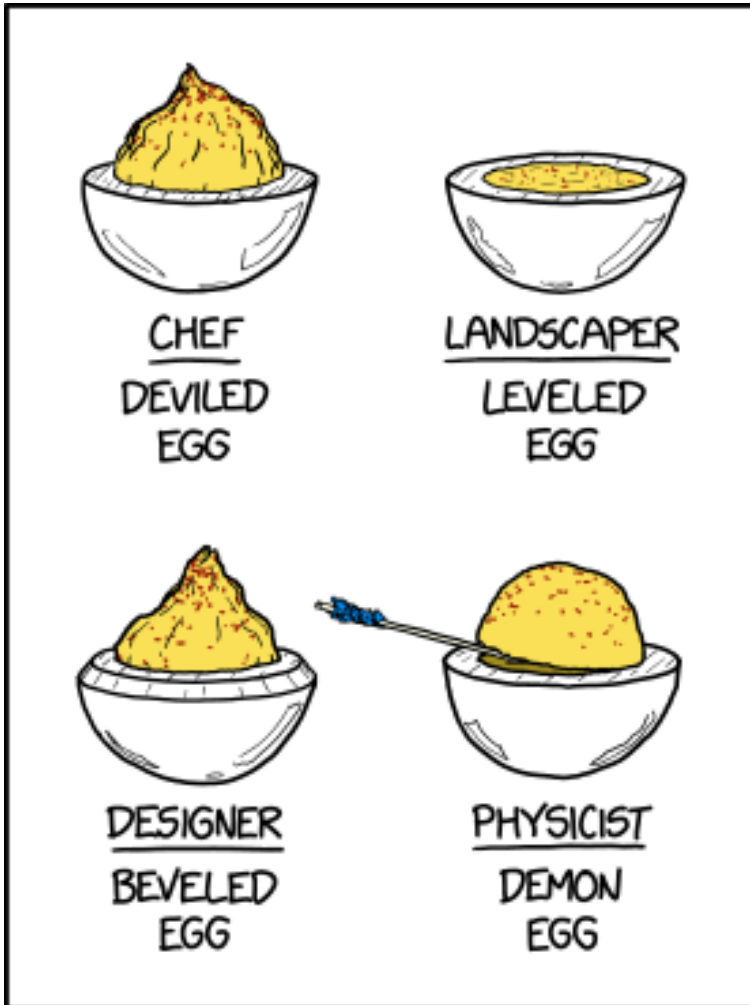
The foil on the toothpick represents the blue flash.

Explanation

A deviled egg is a dish created by cutting a hard-boiled egg into halves and replacing the yolk with a paste frequently made using the yolk itself, additional ingredients such as mustard and mayonnaise, and topped with a red spice (usually paprika). Importantly, the paste has a larger volume than the original yolk because of the ingredients (and probably some air) added into the originally homogeneous yolk substances. Randall Munroe parodies the dish by creating several alternative versions of the dish for other professions using word plays on the name of the dish.

The original dish with the excess paste piled above the egg white.

Many landscaping projects involve leveling irregular ground surfaces.[citation needed] A landscaper may prefer to serve their deviled egg with a leveled flat surface. (This happens to resemble a normal hard-boiled egg cut in half.)

Bevels are a design pattern of creating non-perpendicular surfaces between adjacent edges. A designer may prefer to serve their egg with the edge of the white beveled to give their eggs a more modern, aesthetically pleasing look.

This deviled egg is designed to look like the Demon Core which was a sub-critical plutonium sphere manufactured during the Manhattan Project to investigate the

properties of criticality. The Demon Core consisted of three parts: two plutonium-gallium hemispheres and a ring designed to keep neutron flux from "jetting" out of the joined surface between the hemispheres during implosion. The set of plutonium pieces got their name from the 2 criticality incidents that occurred when scientists were investigating this property. The first accident resulted in the death of Harry Daghlian. In the second incident, experimenters covered the core with two neutron reflecting shells separated only by a handheld screwdriver. The screwdriver slipped, causing the core to become completely covered by the neutron reflecting shell, bringing the core past its criticality limit. A large amount of radiation caused the subsequent death of physicist Louis Slotin. The dome of the boiled egg and the toothpick resemble the configuration of the experiment.
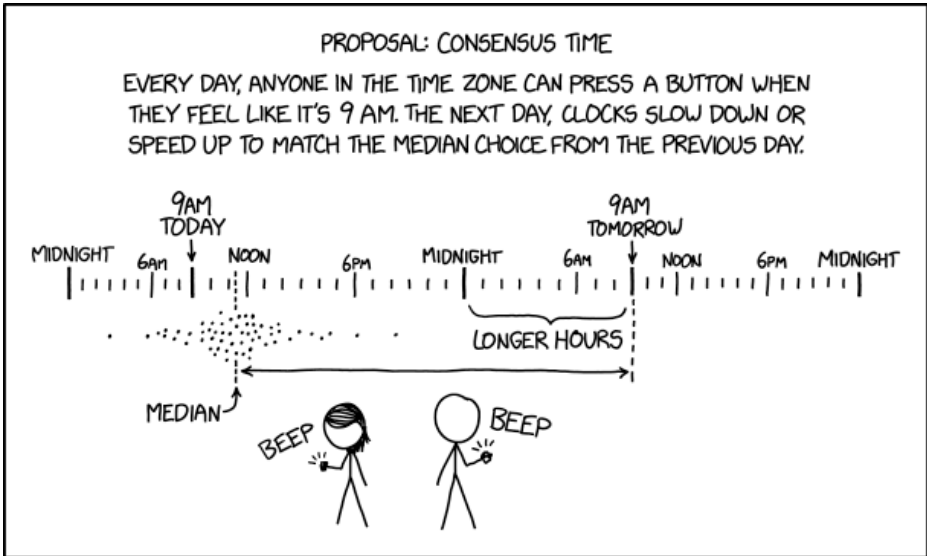
The demon core was also referred to in 1242: Scary Names.

The title texts refers to ionized-air glow, a blue light emitted by air submitted to an energy flux from radiation and seen during the incidents involving the demon core.

For a detailed explanation of the Demon Core, Kyle Hill produced an Youtube Documentary regarding the Demon Core.

#2594: Consensus Time

March 16, 2022

PROPOSAL: CONSENSUS TIME

EVERY DAY, ANYONE IN THE TIME ZONE CAN PRESS A BUTTON WHEN THEY FEEL LIKE IT'S 9 AM. THE NEXT DAY, CLOCKS SLOW DOWN OR SPEED UP TO MATCH THE MEDIAN CHOICE FROM THE PREVIOUS DAY.

Now, you may argue that the varying hour lengths and feedback effects would cause chaos. To which I say, yeah, and I'm also curious to see how the weekday cycle interacts with it! So, you in?

Explanation

Daylight Saving Time, a recurring theme on xkcd, has recently started (in the US, as of this comic's publication). At the time of transition, clocks in (most of) North America are turned an hour forward. People frequently complain about the switch into (and out of) DST, due to it having been invented for the no-longer-relevant cause of saving coal during wartime. One of many complaints is that it will still "feel" like 5 am at 6, or whatever other case. A few days before this comic went up, the United States Senate unanimously passed the Sunshine Protection Act, a proposed law which would permanently abolish the biannual daylight savings adjustment, setting (what was) the local daylight savings time offset as the year-round time zone for all but a handful of states and territories rather than eliminating DST completely. This bill still needs to be debated and passed by the House of Representatives and then signed by the President.

Randall, jumping on this topic, proposes a system that allows everybody to say when it "feels" like 9 am, and then the median 9 am will become the real 9 am. This happens every day. As the title text points out, this would be chaotic and, to put it bluntly, awful.[citation needed]

Presumably the times indicated on this diagram are as the clocks in this time zone would indicate, as opposed to an "ordinary" reference time.

The graph of points seems to follow a normal distribution, with a large number of votes being clustered around a given time, and giving a median of soon after 11AM. There are some extreme outliers, some before 6AM and some after 6PM, indicating some users being outside the normal range but no information on whether it's a malicious attempt.

Although the hours between midnight and 9 am are labelled as "longer" (which we can assume means each would take longer than an hour of ordinary time to pass) the effect on the remaining hours is left unstated. If we assume that the remaining hours pass at the usual rate then this would suggest that midnight would come sooner or later than normal and hence the next vote would occur sooner or later respectively. This implies the time in this time zone could drift further than a day (or even multiple days) from existing time-zones which could be what is meant by "feedback", "chaos" and the effect on weekdays mentioned in the title text.

#2595: Advanced Techniques

March 18, 2022

ALL ADVANCED MATH TECHNIQUES

A blow from Emmy's Cutlass of Variations will transport the dragon to a corresponding symmetric position in the Noetherworld.

Explanation

In typical Miss Lenhart fashion, she is teaching a mathematics class where she outlines a process by which a mathematical result is achieved through steps which sound suspiciously like magical RPG logic. She includes both a dragon and arrows to slay it.

One of her students asks if this is a metaphor for the technique, but her rather tetchy reply "Does this look like English class?!" seems to imply that she literally means that dragons and arrows will be employed in the resolution of the problem. It is also clear from the slide she is pointing at that she has drawn a dragon and a man with a bow that is aiming an arrow at the dragon. Whilst metaphor is an important part of many languages, and so is definitely taught in language classes, it is not usually used in math classes.

The caption beneath the comic states that this approach describes "All advanced math techniques." This could be a reference to the now-common approach in higher mathematics in which a problem is transformed into another domain where it is easier to solve, then transformed back. For instance, in Fourier analysis, commonly used for analyzing the behavior of signals or dynamical systems, a problem can be transformed from the time domain to the frequency domain, solved, and then transformed back again. A (much) more complex example is Andrew Wiles's proof of Fermat's Last Theorem, which uses modularity lifting to transform the

problem. Here Miss Lenhart says she will transform a math problem into an actual dragon, slay it, and transform the corpse back into mathematics.

An alternative view is that Randall is referring to Arthur C. Clarke's third law that Any sufficiently advanced technology is indistinguishable from magic, as re-framed for mathematics. What Randall would be implying is that all advanced math techniques look like magic to non-mathematicians. (Another advanced and somewhat magical math technique is deployed by Miss Lenhart in 1724: Proofs.)

Invocations are a common classification for spoken or vocalized types of spell. In the logic Miss Lenhart used, 'invoking' Gauss's operator may refer to casting a magical spell with verbal components (such as True Polymorph). The operator is presumably named after the famous German mathematician Carl Friedrich Gauss. There is nothing on Wikipedia called Gauss's operator, but there is both Gauss's law and the Gauss–Kuzmin–Wirsing operator. As neither can transform an equation into a dragon,[citation needed] it's clear Randall is making a joke.

Slaying the dragon with Hilbert's arrow indicates that the arrow has some magical properties. Mathematical notation uses arrows for certain relations and operations, for example for expressing limits of a series or function, or Knuth's up-arrow notation used for denoting hyperoperations more complex than multiplication (i.e. exponentiation, tetration, pentation etc.). The latter is

usually used for concisely describing huge numbers that would otherwise be impossibly difficult to write out, like Graham's number. Vectors are also frequently represented as arrows. This (fictional) arrow is presumably named after David Hilbert, known for many mathematical developments including Hilbert's problems and Hilbert spaces. A Hilbert space converts subsets of an infinite vector space into a complete metric space, allowing the use of linear algebra and calculus methods which might otherwise be applicable only to finite Euclidean spaces. Another observation to note is that in 1928, one of Hilbert's students, Wilhelm Ackermann introduced the Ackermann function, a fast-growing function very similar in function (pun intended) to Knuth's up-arrow. Magical arrows are frequently used to slay dragons in myth and role-playing games. Magical items in RPGs such as Dungeons & Dragons are often named after a creator or famous user; hence, a magical "Arrow of Hilbert" might traverse infinite spaces or affect targets for which one or more stats are effectively infinite.

There is in fact a class of Dragon curves, which do have the sort of S-shape shown on the whiteboard, but they have no connection to Gauss's operator, and are not actual dragons that need slaying.

The title text contains two puns and a reference. The phrase "Cutlass of Variations" is a pun on the mathematical technique called "Calculus of variations". The word "Noetherworld" is a pun on "netherworld". The reference is to the mathematician Emmy Noether, a

giant in the field of abstract algebra which, through more of Ms. Lenhart's questionable transformations, may become an actual giant in a field of abstract algae bras. Furthermore, Noether's Theorem is used in the Calculus of Variations. She was previously referenced as one of many important women in science back in 896: Marie Curie.

OPEN THIS PICTURE
FULLSCREEN ON YOUR
PHONE AND HOLD IT
AT ARM'S LENGTH.

THERE ARE
50,000 GALAXIES
IN THIS CIRCLE.

ASTRONOMY FACT: THERE
ARE TOO MANY GALAXIES.

I know it seems overwhelming, but don't worry; I'm sure most of them have only a few stars, and probably no planets.

Explanation

This is another comic with a Fact, the second in a row of these fact comics to use an Astronomy fact.

Our best approximation of the number of galaxies in the observable universe is about 200 billion (2 × 1011). That's a lot of galaxies,[citation needed] and here Randall exemplifies this by showing a small circle and estimating that when the comic's picture is viewed at a typical arm's length, expanded to full screen on your typical smartphone, the circle contains roughly 50,000 galaxies (that means of course not the small circle itself, but the volume defined by the viewer's eye, that circle, and an onward conical extension into deep space — and simultaneously back in time — to the respective limits of the observable universe). Most of those far-away galaxies are undetectable by even our most powerful astronomical instruments today, and comparatively few could be seen (let alone positively identified as such) by the naked eye. For example, in the Hubble Deep Field, an image of a small region in the constellation Ursa Major, about 3,000 visible galaxies can be identified.

Measuring in the mid-point of the lines, the circle is about one fortieth of the width of the frame of the comic. The absolute circle size depends on the display resolution, size and mode, but it can reasonably be taken to be 1mm diameter, or 0.5mm radius, giving a total area π r2 or about $\pi/4$ square millimeters. You're probably holding the phone about a half a meter away from your

eye. The surface area of a sphere is $4 \pi r2$. With a radius of one-half meter, that comes out to be π square meters. Thus, the area of the circle is about 1/4000000 of the area of the sphere, 200 billion galaxies divided by 4 million is the 50,000 average mentioned in the cartoon. A similar mathematics was used for the comic 1276: Angular Size, in which the projective sphere was at the Earth's own radius and cross-sectional areas of objects were compared, rather than an approximate count of objects within a given angular spread.

While galaxies usually are between 3,000 to 300,000 light-years across and contain between 10^8 (100 million) and 10^14 (100 trillion) stars, most are so far away from the Earth (upwards of billions of light-years) that they are invisible to the naked eye, or even through most telescopes. When magnified across such vast distances, even something as small as a pinhole expands to huge sizes, easily able to fit tens of thousands of galaxies.

The premise of this comic is that although galaxies are giant, space is unimaginably big and contains a vast number of things. Randall is apparently overwhelmed by this, as shown in the caption: Astronomy Fact: There are too many galaxies.

The title text is Randall reassuring his readers why not to worry about this overwhelming fact. He states that most galaxies only have few stars and probably no planets. However, as mentioned above each galaxy contains a huge amount of stars, and as evident from all his own

comics about exoplanets, it is now clear that many of the stars in a galaxy also have planets orbiting them. Thus the number of stars and planets in that small circle is much more mind-bogglingly large, than the number of galaxies, and thus the reassurance is sarcasm.

In 975: Occulting Telescope Cueball expresses a similar sentiment about the number of stars.

#2597: Salary Negotiation

March 23, 2022
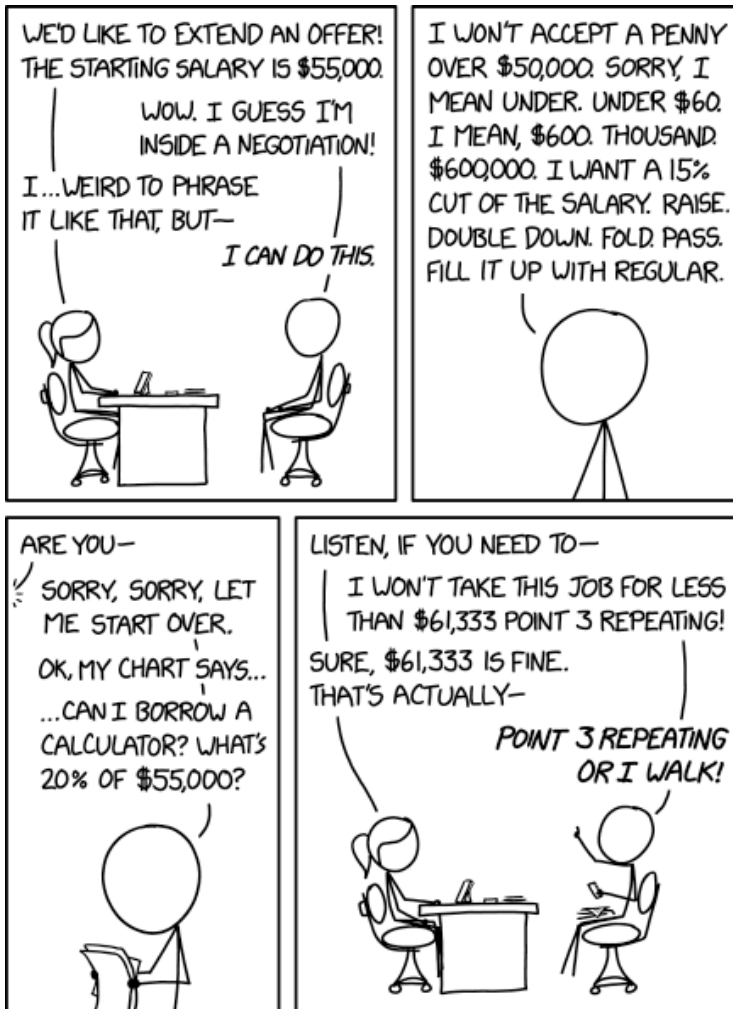
"We can do **0.33** or **0.34,** but our payroll software doesn't allow us to--" "**NO DEAL.**"

Explanation

Ponytail's company would like to hire Cueball for a job, and she is telling him that their offer for his starting salary is $55,000.

When offered a new job, it is common to negotiate on aspects of the offer such as salary, and employers may offer below the market rate initially in the expectation that the final negotiated amount will be higher. Given that the bedrock of one's future income depends on the outcome of a one-time process requiring skills unrelated to the job one is hired for, it is advisable to take one's time and do as much research as possible.

Cueball has clearly done some research, but perhaps too much as he is confused by this high-stakes situation and starts to ramble with decreasing coherence. First he gets completely confused about the numbers. He says he won't have a penny over $50,000, thus cutting $5000 of the initial offer, and saying he will not have more than that. He realizes this was completely wrong, and corrects to "under", but is still 5000 lower. He then fumbles his words, asking for $60, then $600, then adding "thousand" for $600,000.

Realizing that he is completely off, he asks for a "15% cut of the salary". Here, Cueball seems to confuse salary and commission. "X% cut of the salary" seems like what a recruiter/headhunter may get from their employer as a commission if they successfully make their person hired.

The next word he says is "Raise". This could make sense if he already had a job, and wished to negotiate for a pay raise. After this, he begins to think of raise as in a card game and starts rambling off mainly poker related terms, like "raise", "fold" and "pass". He throws in "double down" in between. This can also be a card game term, as in blackjack where double down means to double a bet after seeing one's initial cards, with the requirement that one additional card be drawn. Lastly, he randomly mentions "fill it up with regular", which could be a request to a gas station attendant to fill a vehicle with "regular" (compared to higher octane) gasoline.

Ponytail tries to ask him something, but Cueball interrupts her, saying he is sorry and that he would like to start over. At this time he takes out several sheets of paper and looks at some charts. He asks if he can borrow a calculator and then asks what's 20% of $55,000. (This would be $11,000.) He eventually settles on a number, $61,333.3 He even states that the decimals of 3 should be repeating, as in forever. This is exactly $61,333⅓. He clearly states he will not take the job for less than that. A 2016 Harvard Business School study found that avoiding round numbers is a remarkably effective negotiation tactic.

Since this is not that much more than the starting offer Ponytail is ready to accept this and says "Sure, $61,333 is fine." But Cueball interrupts her because what she just offered him was 33⅓ cents less than he asked for.

In the title text it shows that this is not good enough.

Cueball has now confused himself to the point he will only accept exactly what he asked for, the bizarre amount $61,333⅓. Ponytail tries to explain to him that the point 3 repeating cannot be paid in whole cents, and tries to let him know that their payroll software only can handle whole cents, and he thus can get either 0.33 or 0.34 (the latter actually being more than he asks for). Alas, Cueball, either out of panic or a love of mathematics, shouts "No deal!" and lets the job slip out of his hands, because he has completely misunderstood the concept of negotiation.

This could also be taken in series with Cueball (possibly as a stand in for Randall) misunderstanding classically "adult" ideas, see for instance 616: Lease, 905: Homeownership, 1674: Adult and 1894: Real Estate.

#2598: Graphic Designers
March 25, 2022

IF YOU WANT TO SET UP A VAMPIRE-STYLE BARRIER TO KEEP GRAPHIC DESIGNERS FROM ENTERING YOUR HOUSE, JUST PAINT EVERY SURFACE A SLIGHTLY DIFFERENT SHADE OF OFF-WHITE.

They might make it past that first line of defense. For the second, you'll need some picture frames, a level, and a protractor that can do increments of less than a degree.

Explanation

Cueball is inviting Knit Cap into his newly repainted residence. Knit Cap is a graphic designer and he simply can't enter because of the color scheme used. The caption explains that if you paint each wall a slightly different shade of off-white, a graphic designer will be so repulsed that they are physically unable to enter the room. This is analogous with a specific bit of vampire lore: Vampires cannot enter a dwelling uninvited.

Being presented with visual information that is just not quite right is known to cause feelings of unease and revulsion, particularly when presented with CGI human faces, a concept known as the uncanny valley. This may not be strictly an attempt to annoy, but it portrays a similar vibe to those which are.

In the title text, it mentions a contingency against the designer managing to actually overcome this disgust. In this case, Cueball sets up a second way to troll his graphic designer friend using some picture frames, a level, and a protractor that can measure increments of less than a degree. Cueball can then skew his picture frames by an extremely small amount, noticeable only to the designer friend, to disgust him even further — similar to the effect of bad kerning. This could thus be applied as with the use of crosses or garlic, which vampires are famously repulsed by.

Although the window ledges are slightly inclined, falling

subtly from left to right, it is unlikely this is a deliberate aspect of the room so much as a side-effect of Randall's imprecise stick-figure drawing style.
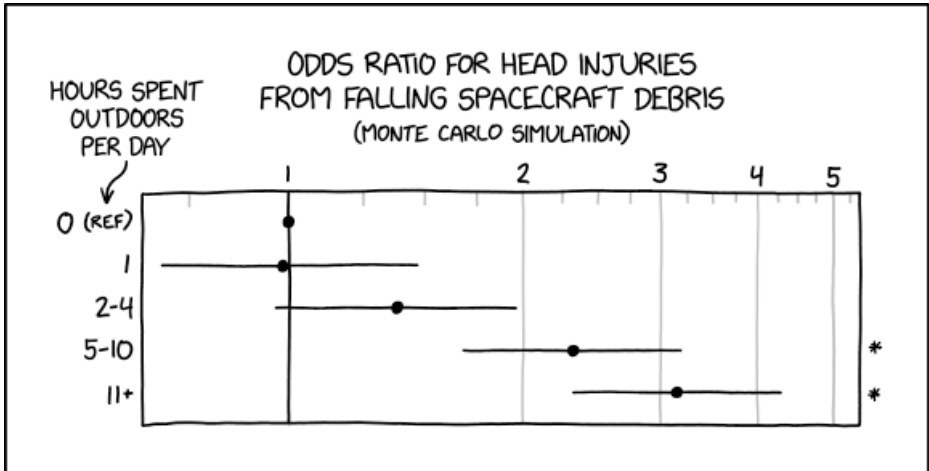
Colors[edit]

True to the comic's joke, Randall has actually colored each segment of the comic differently to each other, even though normal persons would just perceive all walls as slightly gray (off-white).

The hexadecimal color codes are:

- Floor: #FFFFFF [White]
- Ceiling: #F3F7F8 [Light Grayish Cyan]
- Walls (left-to-right)

  #F2F0EE [Light Grayish Orange]

  #F3F4F2 [Light Grayish Green]

  #F2F3F4 [Light Grayish Blue]

  #F3F2F4 [Light Grayish Violet]

- Door: #F1F3F1 [Light Grayish Lime Green]
- Left window frame/ledge: #F2EEF2 [Light Grayish Magenta]
- Right window frame/ledge: #F3F3F1 [Light Grayish Yellow]
- Box seat top: #EEF1EC [Light Grayish Green]
- Box seat front: #F2EEF0 [Light Grayish Pink]
- Rug outer ring: #F0F2F1 [Light Grayish Cyan - Lime Green]
- Rug inner panel: #F0EFF1 [Light Grayish Violet]

#2599: Spacecraft Debris Odds Ratio

March 28, 2022

ODDS RATIO FOR HEAD INJURIES FROM FALLING SPACECRAFT DEBRIS (MONTE CARLO SIMULATION)

HOURS SPENT OUTDOORS PER DAY

OUR NEW STUDY SUGGESTS THAT SPENDING MORE THAN 5 HOURS OUTSIDE SIGNIFICANTLY INCREASES YOUR RISK OF HEAD INJURY FROM SPACECRAFT DEBRIS, SO TRY TO LIMIT OUTDOOR ACTIVITIES TO 4 HOURS OR LESS.

You say this daily walk will reduce my risk of death from cardiovascular disease by **30%**, but also increase my risk of death by bear attack by **300%**? That's a **280%** increased! I'm not a sucker; I'm staying inside.

Explanation

This comic is a misunderstanding of statistics very similar to that of 1252: Increased Risk. It suggests that going outside for more than 5 hours per day significantly increases your risk of head injury from falling spacecraft, and advises to limit outside activity to avoid this risk.

The data are apparently based on a Monte Carlo simulation, a computational method that uses input values randomly drawn from a given distribution and which repeats that calculation many times; the distribution of the outputs is then analyzed. This method is used to determine the possible outcomes (and their respective probabilities) for a given scenario. Basically, instead of doing hard math to calculate the outcomes you let a computer repeat the scenario for a huge number of different input values and watch what happens.

In this case, the study might have consisted of defining the baseline probability of spacecraft debris falling from the sky in a given time frame (say, 1% every minute) as well as the probability that it is heavy enough to break through the roof (say, also 1%), translating this to the output of a random number generator (e.g. "1" means "space debris falls in direction of head and can break through the roof", 2-100 means "space debris falls in direction of head but can't go through a roof" and values 101-10000 mean "no danger from space debris"), adding another random number generator to simulate the

distributions for "person is outside X hours of the day", then drawing numbers repeatedly from both distributions and calculating the outcome for each instance.

Doing a Monte Carlo simulation for a hypothetical and rare scenario like this can make sense: it is so rare for humans to be struck by spacecraft debris that an absurdly large sample size, involving tens of millions of participants over several decades, would be necessary to obtain significant experimental data.

However, the statistical analysis and presentation of the data is horribly misleading and sensationalizing. The comic essentially pokes fun at the way that data can be misrepresented and exaggerated using an example that people would realize is absurdly unlikely.

The results are presented not as an overall probability but rather as an odds ratio of the probabilities. The odds ratio is defined as p(A happens in presence of B)/p(A happens in absence of B), which here would be p(space debris head injury after Xh spent outside and 24-Xh inside)/p(space debris head injury after 24h spent inside). The resulting value tells you how much more likely an outcome becomes if you do (or have) A. E.g. the bottom line of the graph in the comic means that spending 11+ hours outside will make it 3 times as likely to get a head injury from space debris compared to not being outside at all.

However, while odds ratios can be useful they tend to hide the scale of a probability - e.g.

0.00000000002%/0.00000000001% = 2, the outcome became twice as likely but the probability only rose by 0.00000000001%. And since the odds of being hit in the head by (any part of) a falling spacecraft are astronomically (no pun intended) low to begin with, even quadrupling it still results in a negligible probability.

The choice of hour brackets instead of a linear time scale is suspicious. Monte Carlo simulations involve a huge number of computations; the scientists should have more than enough data to plot the odds ratio for every additional hour spent outside. Moreover, each hour bracket has a different size - why didn't they use a regular binning like e.g. 1-3, 4-6, 7-9, 10-12? One might suspect that they wanted to conceal inconsistencies and that the underlying data points by themselves don't look nearly as convincing.

Moreover, range-based groups of any kind should never be analyzed as if they were independent categories. Spending 5 hours outside is not intrinsically different from spending 1 hour outside - the 5-hour-mark (presumably) doesn't suddenly turn humans into space-debris magnets. The likelihood of space debris falling down at any given moment stays the same and the cumulative (i.e. summed-up) probability should increase at a constant rate. Instead of comparing every hour bracket to the same baseline reference, each should each be compared to the next-lowest value.

The error bars (the lines extending from the points in the

graph) are HUGE compared to the effect they measured. Error bars define the range in which the true value might be - here, for 2-4 hours the true value could be an increase by 2, or a small DEcrease of the probability.

The data are shown on a log scale. Logarithmic scales are used when you have both very small and very large values and want to depict their relative differences in a single plot without making the small values look like zero or cutting off the large values. The data shown here do not have huge differences - there is no good reason for using a log scale. However, the log scale is conveniently chosen to make the error bars look like they have the same length. They do not. The error bar for the last data point is actually twice as large as that for the first data point.

The title text continues the misuse of statistics by insinuating that a 30% decrease of cardiovascular disease resulting from going outside (and exercising) is outweighed by a simultaneous 300% increase of risk of being killed by a bear. As shown in 1102: Fastest-Growing, the percentage increase/decrease alone of something has little meaning; the context of the original size is needed to evaluate how impressive the change really is. And in this case, the probability of dying from a cardiovascular disease is much, MUCH higher than the probability of being attacked and killed by a bear, so the moderate decrease of the former has much more impact on one's overall life expectancy than even a huge increase of the latter (unless you live in an area that has many bears, in which case your best bet is to take appropriate precautions rather than to never go outside

at all).

The "280% increase" of the title text is also an error, though perhaps not for reasons you might assume at first glance (the correct calculation is not "300% − 30% = 270%"). To "increase by 300%" means to add 300% on top of the original 100% (=400%, so multiplied by 4), while to "decrease by 30%" means to remove 30% from the original 100% (=70%, so multiplied by 0.7). Combining these (which is very very wrong!) would mean multiplying by both, for an overall change of 4.0 × 0.7 = 2.8, or 280%. However, this should be read as an increase to 280% of its old value, not by 280% (you started at 100% and added 180%). But this is a very, very wrong way of doing the math because these are probabilities of very different things with very different scales (if you threw out 30% of your dishware but in that same period also acquired 3 toothpicks on top of your original 1 toothpick, would you say that your kitchen stuff increased by 180%?). The correct way of combining the two probabilities would be to translate them onto the same scale - the overall chance of death - which would be done by multiplying each value with its probability of happening at all. For example, if the chance of dying from cardiovascular disease was 50% and the chance of being killed by a bear was 0.1%, the overall chance of dying from either would be the sum, 50.1%. Both probabilities are affected by going outside; the new chances are now 50%*0.7=35% and 0.1%*4=0.4% and the combined chance of dying from either is now 35.4% - a significant DEcrease from the original 50.1%.

The specific reference to falling spacecraft is likely inspired by events happening around the time of this comics release (March 2022). Around a month before this was posted, the head of the Russian space agency, Roscosmos, warned that sanctions against Russia (mostly those over the 2022 Russian invasion of Ukraine) could result in the International Space Station crashing. Since the Russian section of the space station is the one that provides propulsion (although it is built to rely on the power generated by the other sections), this was taken seriously and as of when this was posted, NASA was trying to come up with alternative stabilization strategies in case the situation worsened. There was also a recent report of some 600 kg space rocket debris found in Brazil.

#2600: Rejected Question Categories

March 30, 2022

IN *WHAT IF? 2* (xkcd.com/whatif2), I ANSWER RIDICULOUS QUESTIONS SENT IN BY READERS ABOUT EVERYTHING FROM VOLCANOES TO SPACESHIPS TO SOUP.

HERE ARE A FEW OF THE COMMON TYPES OF QUESTION THAT I DID *NOT* ANSWER:

PEOPLE CHEATING ON HOMEWORK

WHAT IF I MADE A PENDULUM BY HANGING A ROCK ON A 2.75 METER STRING? WHAT WOULD ITS PERIOD BE IN SECONDS? (SHOW YOUR WORK!)

MEDICAL ADVICE

WHAT IF YOU GOT A SCRATCH AND THE NEXT DAY YOUR HAND LOOKED LIKE THIS [📎 ATTACHMENT]? SHOULD YOU SEE A DOCTOR OR WHAT?

PERSONAL

WHY DON'T THE SQUIRRELS IN MY YARD LIKE ME???

SPAM

DO YOU WANT TO MEET LONELY SINGLES IN YOUR AREA TONIGHT?

PHISHING

HAVE YOU RECENTLY BEEN THE VICTIM OF PHISHING? TO CHECK, LOG IN TO YOUR ACCOUNT BY CLICKING HERE.

REQUESTS FOR HELP WITH A CRIME

USING MODERN SCIENCE, WHAT WOULD BE THE FASTEST WAY TO GET THROUGH THIS BANK VAULT DOOR? [📎 BLUEPRINTS]

UNANSWERABLE

WHY AM I ME AND NOT SOMEONE ELSE

VAGUE

WHAT IS GOING TO HAPPEN? (BE SPECIFIC)

VAGUE+OMINOUS

WILL I HAVE TO START WORRYING ABOUT SPIDERS AFTER TUESDAY?

?????

HI, WE'RE LONELY SINGLES IN YOUR AREA, AND WE'RE WONDERING WHAT WOULD HAPPEN IF WE SHOT A NUCLEAR BOMB INTO A VOLCANO! CLICK HERE TO LOG IN AND TELL US

You can click to preorder to get a copy of What If? 2 when it comes out 9/13, assuming we all make it past the spider situation(?) on Tuesday(?).

Explanation

Randall recently announced, in 2575: What If? 2, that he is publishing a new What If? book based on reader-submitted questions. This comic is another promotion of the book, and the entire comic is a link to his what if? 2 page on xkcd.

This comic shows the categories of questions he claims to have received, but rejected to use in his book, giving an example question for each category. In typical xkcd fashion, these begin out by being plausible, although often unlikely to have been submitted as a what if? question, moving in to more and more absurd types of questions, especially with the last question, that appears to be a combination of all previous categories and is therefore marked "?????"

The title text refers to the launch date of the book September 13, rendered in the American style 9/13. This format can be confusing to non-Americans, although usually not when the date is larger than 12, since it would then appear to reference the 9th day of the 13th month. This "13th month" was, however, referenced in the first comic about the book: 2575: What If? 2. See also Randall's take on the date format, ISO 8601, in 1179: ISO 8601.

Randall then continues the title text by referencing the second to last category with vague ominous questions. The example question here asks if there is need to worry

about spiders after Tuesday. So Randall notes that the release date, 5.5 months after the release of this comic, is of course assuming anyone will survive past next Tuesday (2022-04-05).

Tuesday has been notably referenced in 277: Long Light, 564: Crossbows, 1099: Tuesdays and most notably in 1245: 10-Day Forecast, where it seems that the last day ever will be a Tuesday. Tuesday is the second day of the week, and notably, the Tuesday of the week following the publication of this cartoon (April 5th, 2022) was the Day of the Spiders.

"Spaceships and Soup" is a reference to the first chapter of What If? 2, where Randall looks into filling the Solar System with soup.

#2601: Instructions

April 01, 2022
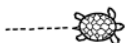
Happy little turtles

Explanation

This is the 12th April fools' comic released by Randall. The previous April fools' comic was 2445: Checkbox, which was released on Thursday, April 1st, 2021. The next became 2765: Escape Speed released on Friday April 19th, 2023 (a regular release day, but 18 days late).

The comic displays just a small radio button (or option button). Usually, there would be more than one to give the user options. Once it has been selected it cannot be deselected. Once pressed the button turns blue and this starts the real part of this April fool's comic.

The comic consists of an audio file. The speech is a mix of facts about turtles and coding instructions in LOGO. When executed, the instructions draw an xkcd comic. The audio file is 9 hours and 7 minutes long.

• See the resulting comic below.

And see how it is animated here.

This has been compiled by theinternetftw on Github.

• The transcript of the quotes (the non-code) can be found here 2601: Instructions/Audio Transcript.
• Images of the dynamic changes and other pictures relating to this comic can be found here 2601: Instructions/Images.

Once the voice begins to describe the instructions (hence

the title) it is possible to mute the audio by pressing a muted button at the bottom right of the screen. This fades into view when the radio button is pushed. Pressing it will change the button to a non muted loudspeaker. These were the same buttons that were in the previous April fool's comic 2445: Checkbox. That was the first xkcd comic with audio, and thus these were two April fools' comics with audio in a row, and these are the only comics with audio. In the Checkbox comic, the mute buttons meaning are reversed, so the sound is on when the loudspeaker is shown and muted when the mute button is shown. It could be another layer to the April fool's joke or just an error by Randall.

The image originally displayed on this page was of a small turtle crawling in the center where the radio button is in the real comic. That was the image that would be downloaded by web crawlers like explain xkcd's bot, as it is what was placed here on xkcd: https://imgs.xkcd.com/comics/instructions_2x.png. This is of course not the real comic, which cannot be downloaded in that manner.

The "turtle" is a key concept in Logo, a programming language especially designed to teach programming to children in an easy way. The turtle in the logo is the cursor. Programming commands move the turtle, drawing a line as it goes. Of course, listening to hours of instructions, including the speech-synthesized reading of source code, is not an easy way to code or draw a picture.[citation needed]

In addition, at the end of the audio the voice says:

The title text alludes to Bob Ross's catchphrase "happy little trees" in The Joy of Painting, a PBS TV show in which Ross leads the viewer through the painting of a nature scene. The audio file itself is also presented in the style of The Joy of Painting; it begins with greeting the viewer and introducing the color palette to be used (just one color, in this case, as Logo and all computer monitors of the time were monochrome). The speaker then reads out some helper functions to be used in programming the scene, which is more analogous to Ross's palette of paints (titanium white, carmine red, etc.) along with words of encouragement as each is completed. The functions are DIST, to calculate the Euclidean distance between two points, LERP, to perform linear interpolation, MIX to average two numbers (with LERP), and CUBIC to draw cubic Hermite splines. From there, the speaker alternates between sketching parts of the scene and offering more words of encouragement, mixed in with turtle facts.

Transcribing the audio into text was organized as a project on github.

This is not the first time that Randall made an interactive comic where turtles played a big part, see 1416: Pixels. In this, he jokes with the idea of turtles all the way down, which is also mentioned in the audio file. He also made a comic simply called 889: Turtles.
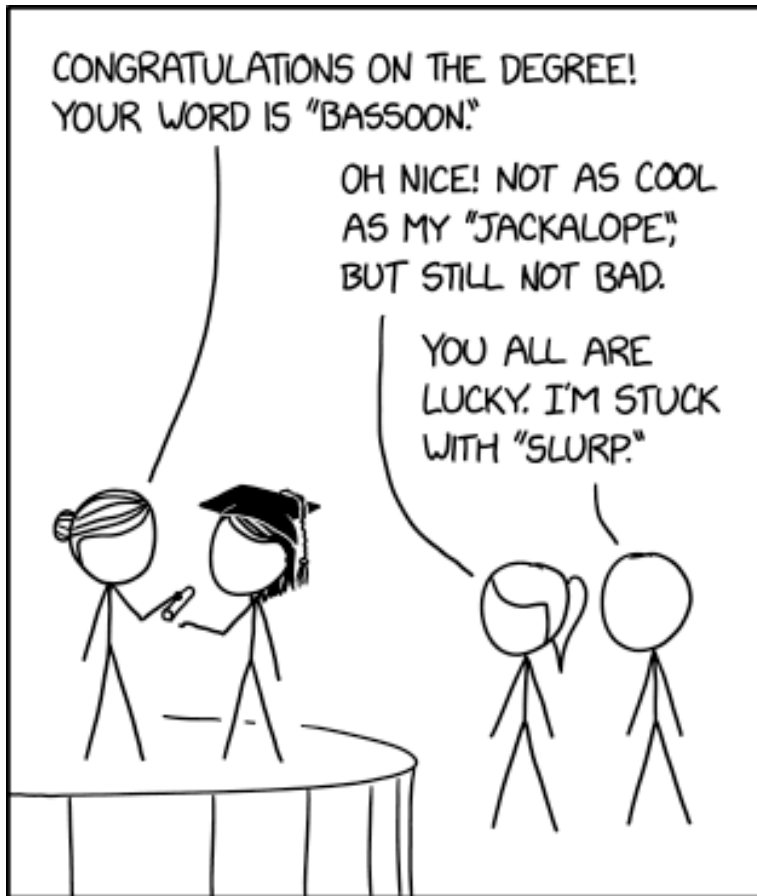
Unique header text[edit]

This comic has a unique header text, see the details here. The header is:

The header had not changed since the promotion of the new what if? 2 book.

#2602: Linguistics Degree

April 04, 2022

CONGRATULATIONS ON THE DEGREE! YOUR WORD IS "BASSOON."

OH NICE! NOT AS COOL AS MY "JACKALOPE," BUT STILL NOT BAD.

YOU ALL ARE LUCKY. I'M STUCK WITH "SLURP."

EVERY LINGUISTICS DEGREE COMES WITH ONE WORD THAT YOU'RE PUT IN CHARGE OF.

You'd think 'linguistics' would go to someone important in the field, but it's actually assigned to a random student in Ohio who barely graduated and then went into automotive marketing.

Explanation

Hairbun hands Megan a linguistics degree, and informs her she is now "in charge of" the word 'bassoon.' Watching this, Ponytail and Cueball compare the words they were assigned when they got their linguistics degrees, 'jackalope' and 'slurp' respectively. Ponytail thinks bassoon is a cool word but thinks her own is better, whereas Cueball is not satisfied with his word. A bassoon is a woodwind musical instrument with a double reed, while a jackalope is a mythical creature, a jackrabbit crossed with an antelope. "Slurp" is an onomatopoeia associated with eating or drinking loudly.

It is never clarified what being "in charge of" a word entails. It could mean being in charge of keeping track of the word, or having actual authority over the use of the word, which is unlikely as normally language use cannot be dictated by a single person. Also, no specific university has control over all of linguistics as far as we know, so it would require every university capable of giving people linguistics degrees to co-operate, so nobody is assigned the same word. Any well-educated member of the linguistic community will know what is being suggested is impossible hence why they are the only ones aware of how important it is.

The title text merely furthers how seemingly random the entire situation is. The word "linguistics" was assigned to a "random student in Ohio who barely graduated and then went into automotive marketing", who we can

assume isn't very important to the field of linguistics.[citation needed] But this means that no one is actually taking care of this important word, since it must be assumed that the student is no longer interested in linguistics.
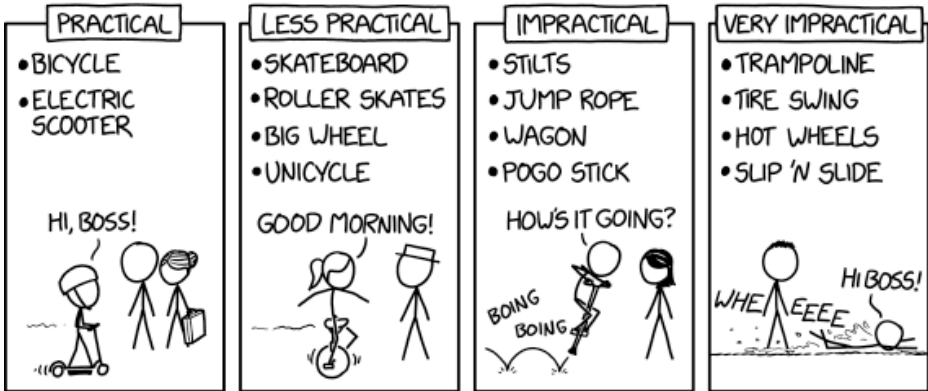
The idea of individuals having a guardianship of an idea or concept has appeared in science fiction. For example, in Fahrenheit 451 characters have memorized books to save them from book-burning and... spoiler-stuff.

It also exists in reality. Members of the Royal Spanish Academy, the institution that defines the official dictionary of the Spanish language, are symbolically put in charge of one letter of the dictionary each to take care of it.

#2603: Childhood Toys

April 06, 2022

CHILDHOOD TOYS
BY PRACTICALITY FOR COMMUTING

PRACTICAL
- BICYCLE
- ELECTRIC SCOOTER

HI, BOSS!

LESS PRACTICAL
- SKATEBOARD
- ROLLER SKATES
- BIG WHEEL
- UNICYCLE

GOOD MORNING!

IMPRACTICAL
- STILTS
- JUMP ROPE
- WAGON
- POGO STICK

HOW'S IT GOING?

BOING BOING

VERY IMPRACTICAL
- TRAMPOLINE
- TIRE SWING
- HOT WHEELS
- SLIP 'N SLIDE

WHEEEEEE

HI BOSS!

The rope keeps breaking, I'm covered in bruises and scrapes, and I've barely reached the end of my driveway, but I don't care--I'm determined to become the first person to commute to work by tetherball.

Explanation

This comic shows various objects, ranked by how practical they would be for long-distance transportation. The objects are described as childhood toys.

The "Practical" panel shows objects designed for convenient transportation, namely bicycles and electric scooters. Most people know how to ride a bicycle, and can easily go several miles on it. Scooters (shown in the comic panel) are also relatively easy to use, and may have a motor allowing them to be used for significant distances — the one shown has the appearance of one with a battery unit rather than being 'leg-propelled', and is named as such in the list for which it has been depicted. These are not considered "toys" at adult size as they are widely used for transport, but children's bikes and scooters (particularly unpowered scooters) not used for transport would generally be considered toys. The practicality of bicycles and e-scooters tends to depend more on local infrastructure and amenities (i.e., the presence of a safe cycle route and the destination being within a sensible distance) than on the equipment itself. Bicycles can carry substantial loads. In some countries e-scooters are legally restricted or prohibited on public roads which may make commuting on them unviable.

The "Less Practical" panel has objects designed for transportation, but which may be harder to use than the first panel. Skateboards and roller skates, while designed for transportation, don't work great over long distances

or when carrying objects, and Big Wheels and unicycles (shown in the panel) are simply less practical bikes.

In the "Impractical" panel are objects that are designed for transportation, but are very much not designed for convenience, especially over long distances. Stilts are long poles that one stands on to extend their legs; while they increase the user's stride length, it takes quite a bit of practice to use them, especially if they're very long. A jump rope is a rope that the user swings around their body while they jump over it whenever the rope passes below their feet; it doesn't actually provide any transportation by itself, the user is simply hopping to their destination, which is a very tiring way to travel (but very good exercise if you can do it). A wagon has no propulsion of its own, it has to be pulled by the user; parents sometimes use it to transport their children short distances (such as to a playground). Larger wagons are used commercially. A Pogo stick is a pole with a spring at the bottom and a platform for standing on, which can be used to bounce; while fun for bouncing a few yards (as shown in the panel), like the jump rope it would be tiring for long distances.

The "Very Impractical" panel has objects that may be used for transportation, but to an incredibly limited degree. Slip 'N Slides (shown in the panel) only work (effectively) downhill, and only where they are placed down. Trampolines and Tire swings could let you go somewhere, but you'd need to set up multiple in a row leading to your destination beforehand. Hot Wheels cars could be put onto the bottom of shoes to create

extremely ill-advised[citation needed] improvised rollerskates, but the car on its own has effectively no merit for transportation.

The title text refers to tetherball, a game found in many playgrounds where a ball is attached to a pole by a long rope. This is also very impractical, as the rope just winds around a stationary pole. It's possible that he is swinging from the rope and letting go (which would explain the bruises and scrapes, as well as the torn rope), but there is no remotely practical way to use this to commute.[citation needed] Nevertheless, if you were able to swing quickly enough and cut the rope at exactly the right moment, you might be able to achieve a short commute to a nearby target. This method may have been inspired by NASA purchasing a launch via the SpinLaunch rocket system the same week as the comic appeared.

#2604: Frankenstein Captcha

April 08, 2022

OH NO.

The distinction between a ship and a boat is a line drawn in water.

Explanation

This comic strip is a play on the meanings (and misunderstanding) of the name "Frankenstein". Frankenstein; or, the Modern Prometheus is an 1818 novel by Mary Shelley about a medical student named Victor Frankenstein who creates an artificial life-form. The man he creates once describes himself as "the Adam of [Frankenstein's] labour" in the book, and strictly speaking is properly known as "Frankenstein's monster" (or perhaps "creation" or "son"), but is often erroneously called "Frankenstein" himself. This has been fertile ground for many, many debates about whether the monster could also properly be called "Frankenstein," either as a family name, an honorific, or simply because it's more recognizable and convenient. Randall has weighed in on the debate himself in a previous comic, 1589: Frankenstein, and would do it again in 2799: Frankenstein Claim Permutations.

The CAPTCHA shown in the comic instructs the user to select all tiles containing Frankenstein. The tiles include both a reanimated corpse resembling Frankenstein's monster and a scientist yelling, "It's alive!" who is clearly intended to be Victor Frankenstein. The problem arises from the contrast between various definitions of the term Frankenstein. Going just off the book's text, the monster has no name, so the correct answer to the CAPTCHA is just the left square of the third row. However, the character depicted there is clearly Henry Frankenstein from the famous 1931 film

adaptation (Victor Frankenstein never said the words "it's alive!" in the book), and likewise the creature depicted is clearly inspired by Boris Karloff's iconic portrayal in that film and its sequels. If the images are captured from that film, then all four of them could be said to be "containing (a subset of) Frankenstein (the 1931 film)". Alternatively, if the CAPTCHA user's canonical version of "Frankenstein" is the official xkcd story of Frankenstein (see 1589: Frankenstein), the correct tiles would be row 1 column 3, row 3 column 4, and row 4 column 4.

Some CAPTCHAs - especially Google's widely spread reCAPTCHA - nowadays serve a dual purpose: (1) to separate human users from bots by way of intelligent interaction, and (2) to train a neural network, hence the "correct answer" to image recognition CAPTCHAs is not known ahead of time and is merely based on the most commonly-chosen tiles. Thus, a user who knows that "Frankenstein" refers only to the scientist would face this CAPTCHA with dread, uttering "Oh No" as they realize that they must select the tiles containing the monster, and possibly not even be allowed to select the tile containing the actual scientist Victor Frankenstein if they want to pass the CAPTCHA.

Alternatively, this comic strip with its "Oh No" caption could be a reference to 1897: Self Driving, which would imply that someone had actually created a Frankenstein's monster which needs to be located as soon as possible.

Many of the other tiles appear to be pictures of entities

that inspire similar pedantry. For example, there is a picture of a turtle (or possibly a tortoise, or a reference to the Voight-Kampff test used in a manner analogous to CAPTCHA), a ship (or possibly a boat), Link (the name given to each of several protagonists that appear across generations and timelines, throughout the Legend of Zelda video games, who many erroneously refer to as Zelda), a pond (or possibly a lake, a puddle, or a mirage), a tomato (often subject to the fruit or vegetable debate), an erupting volcano (with lava, or is it magma?), the planet Pluto (or is it a dwarf planet?), and a man and a woman (who may be dating or just friends). Other tiles seem to be inspired by images that commonly occur in actual captchas, like the STOP sign or the traffic light. However, at least some of these may also be meant to fall into the category of entities that inspire pedantry, for example: because traffic lights can also be called traffic signals or stoplights; many people thinking that the shape of a stop sign is a hexagon, not an octagon; and the definition of a sandwich (previously discussed as a "random semi-ironic obsession" in 1835: Random Obsessions).

The title text refers to one of the methods used to distinguish a ship from a boat. When making a turn, if the vessel leans towards the inside of the turn circle, then it is considered a boat, whereas if the vessel leans away from the turn circle it is considered a ship. Since the vessel generates a wake as it moves, checking whether it is a boat or a ship can be done while it is literally drawing a line on the water (the wake). The phrase "a line drawn in

water" is also an idiom for something ephemeral. Ironically, it has persisted for a long time and dates back at least to the early Buddhists. (e.g. AN 3.132 & AN 7.74). The distinction between a ship and a boat is also unclear, having changed over time, with no universally accepted rule to distinguish between the two. The title text is also a pun on the common idiom "drawing a line in the sand." The title text could also be referencing the image of a boat or ship that appears as one of the CAPTCHA tiles in the comic, where Randall has drawn a squiggly line often used in crude drawings to represent a waterline.

#2605: Taylor Series

April 11, 2022

AT THIS POINT, YOU'RE PROBABLY THINKING, "I LOVE THIS EQUATION AND WISH IT WOULD NEVER END!"

WELL, GOOD NEWS!

TAYLOR SERIES EXPANSION IS THE WORST.

The Taylor series should have been canceled after the first term.

Explanation

In mathematics, a Taylor series expansion is a polynomial power series approximation of a function around a given point, composed of an infinite sum of the function's derivatives, each both divided by successive factorials and multiplied by the incrementally increasing power of the distance from the given point. Such expansions usually continue without end. Beyond approximation of functions, Taylor series are also useful for deriving numerical approximations of irrational values, such as π, as well as symbolic forms to make functions easier to integrate or otherwise manipulate with calculus. However, because they involve difficult calculus operations, and can be annoyingly tedious to calculate by hand, they are often not loved by math students.

Miss Lenhart appears to be teaching a class about how to use a Taylor series. She presumes her students want to keep learning about the series, in that they, "wish it would never end." She then says "Good news!" because the series does not end. The cartoon's humor is based on the contrast between wishing the series won't end, ordinarily desired of sequences of enjoyable events, and the infinite nature of the Taylor series, which is less likely appreciated by her students struggling to understand why the sums converge to their resulting value.

The title text is a reference to the common practice among physicists and engineers of abbreviating the Taylor series to only the first few terms, typically one or

two, in order to simplify the mathematics of their models. The title text is also a pun on the use of the word "series" to refer to a television program. It symbolizes the terms of the mathematical series as a metaphor with a television season, suggesting that only the first term is useful. It makes fun of the common sentiment against bad screenwriting of a series by saying that, "The series should have been cancelled after the first season," replacing "season" with "term." (Notably, both "term" and "season" are used to refer to a stretch of time during which a program is airing—generally, a scholastic or television program, respectively.) Also note that US President Zachary Taylor died during his first term. In a way, his presidency was cancelled during his first term.

U+2A0B Mathematicians need to calm down

Explanation

This comic proposes joke explanations for various unicode symbols with obscure or no known uses, see the table below.

It may have been inspired by this blog post U+237C RIGHT ANGLE WITH DOWNWARDS ZIGZAG ARROW. It was posted four days prior to this comic's release. The blog post went viral (in a limited sense) the same day the comic was published, perhaps as a consequence of it mentioning one of the symbols of the comic, Larry Potter. This caused the blogger to update his post with a reference to both xkcd and explain xkcd:

The title text includes yet another special symbol , and this symbol prompts Randall to ask Mathematicians to calm down. See more details in the table below, where the title text symbol is mentioned in the last entry.

Table of symbols[edit]

#2607: Geiger Counter

April 15, 2022

AT FIRST I WAS CONFUSED ABOUT WHY THEY WANTED ME TO CARRY A GEIGER COUNTER HERE, BUT THEN IT CLICKED.
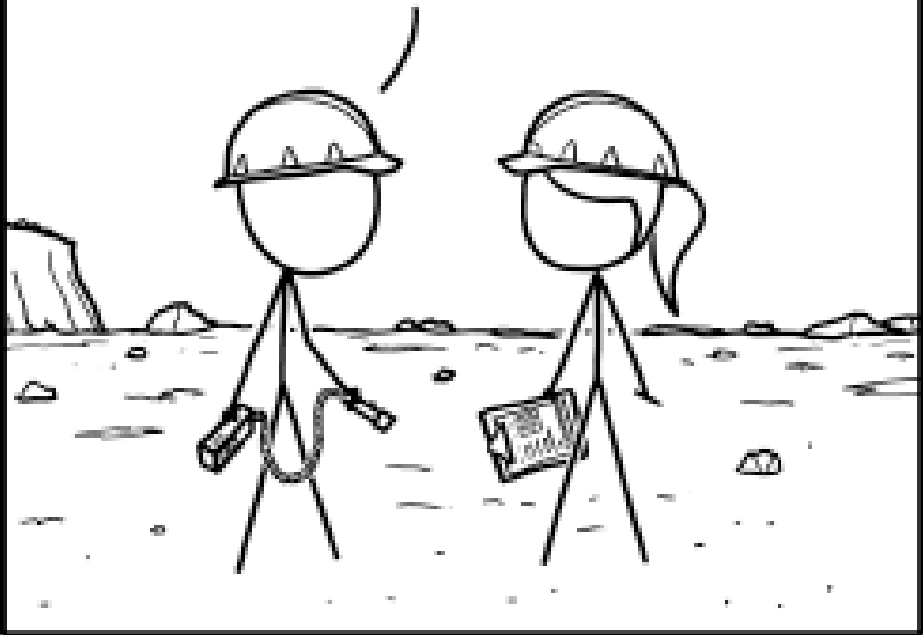
At first I didn't get why they were warning me about all those birds sitting on the wire, but then I understood.

Explanation

This comic is a simple pun. Cueball and Ponytail are standing in what looks to be a desert, and Cueball is holding a Geiger counter in his hand. Cueball remarks that he did not understand why he was asked to carry a Geiger counter, but that it then "clicked" with him.

Geiger counters are devices used to measure the amount of radiation in an area. When a particle of ionizing radiation hits the sensor of a Geiger counter, it will give off a distinct "clicking" noise. "Click" can also be a slang term for the Eureka effect, a sudden moment of understanding. The pun in this comic insinuates that Cueball realized why he was asked to bring the Geiger counter when it clicked, indicating radiation nearby. In radioactive areas, it is usually a good idea to carry around some sort of radiation detector for safety reasons.[citation needed]

This is likely a parody of a fairly well-known pun that takes advantage of a similar double meaning: "I wondered why the baseball was getting bigger. Then it hit me." Just as that pun uses "hit me" to mean both the action of the ball and to understand, this comic uses the "clicking" to mean both the action of the Geiger counter and to understand. A related variety of pun, told in the third person, is the Tom Swifty.

The title text is also a pun, with the implication being the narrator "understood" once they "stood under" the birds

that were perched on the wire (who may have then pooped on the narrator to bring them to their understanding [in the "realization" sense]).

#2608: Family Reunion

April 18, 2022
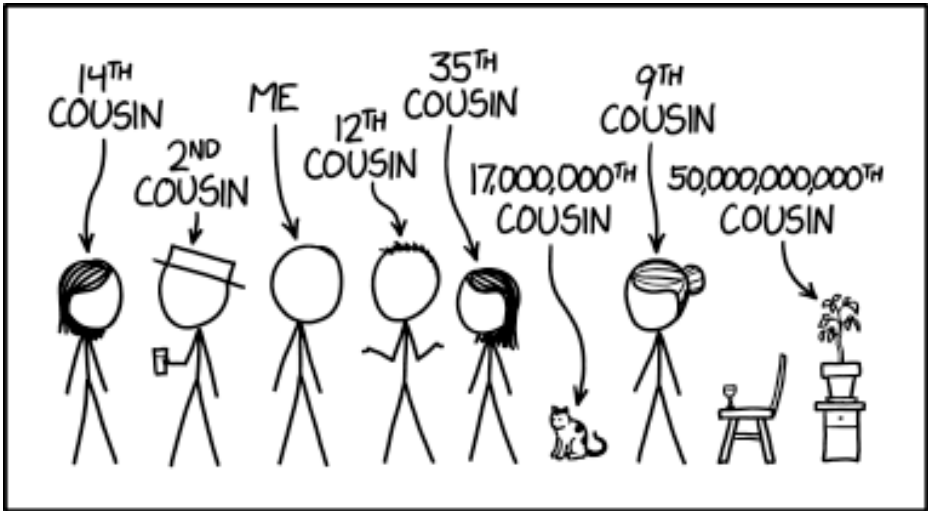
REALLY, *EVERY* GATHERING IS A FAMILY REUNION.

Grandma says that because of differences in primate and feline lifespans, the cat is actually my 17,000,000th cousin 14,000,000 times removed.

Explanation

Because all humans are descended from a common ancestor, every human is, at some point, related to every other human, albeit distantly. Similarly, all life forms on Earth are presumed (with good reasons) to be descended from a single even more distant relative whose ultimate lineage became more relevant than any from its own 'cousins' at the time, and thus all life forms are distantly related. This makes every interaction with another life-form, technically, a family reunion, if not in the traditional sense.

The general English definition of a cousin, which is a person sharing an ancestor who is not a direct parent of either party, can be qualified by two numbers. There is the nth-ness of the relationship (the fewest generations you need to go beyond one's parentage, "a first cousin" implies that a grandparent is the key link) - for example, this Cueball's relation to White Hat is via a great-grandparent, whilst that with Hairbun is through a great-great-great-great-great-great-great-great-grandparent. A "removed" number is any difference in this number between the two individuals, such that a child of a direct cousin invokes a "once removed" relationship between the two (without individually qualifying who is the 'senior' generation, from whom the 'nth' count is determined). You would normally only qualify "first cousin" if this fact is considered important, and "zero times removed" would also be considered implicit.

In this strip, all the humans are shown to be no more distantly related than 35th cousins. This may seem closely related for randomly selected humans, but the number of cousins a given person has increases exponentially with successive degrees of separation. For example, if family lines are separate, each person would have 64 pairs of sixth-generation great-grandparents. How many descendants those grandparents have now depends on how many living children each couple has, and how often breeding lines cross, but [studies in Britain] concluded that the average person in that region has nearly 200,000 sixth cousins. 35th cousins is probably nearly the most distant relationship you're likely to find among people who have ancestors from the same geographical region.

As pointed out in the title text, cat lifespans (or, more importantly, inter-generational breeding cycles) are somewhat different from those of humans. Although they would have still been very similar immediately after the divergence from the appropriate most recent common ancestor (MRCA), the differences will have built up to a generational-count displacement of a similarly extreme nature. i.e. that while the shared ancestor is Cueball's 17-million-or-so-Great Grandparent, the cat is in turn the 31-million-or-so-Great Grandchild. Exactly how accurate, or even precise, Randall considers these numbers is unknown, but it is the kind of fact that we know he likes to research and use expert opinion for.

If we presume that generations of humans (including

proto-humans, pre-humans, etc) since the divergence from cathood (including proto-cats, pre-cats, and the rest, back to the common ancestral form) have averaged around 5 years, then a 17 millionth cousin may be about right. Many of our (and cats') early ancestors will have necessarily been small burrowing mammals — to have been amongst the ones who survived the asteroid around 66 million years ago that killed off most of the dinosaurs — with contemporary equivalents having breeding cycles in terms of a year at the most. But we currently have a large feasible range of generational cycle (15-50 years, very roughly, with or without technical/social help or hinderances), that may have started to drag our long-term average upwards since at least the age of the early hominids, if not the age of our primate forebears or earlier.

To get a 50 billionth cousin from the potted plant, then the generations of (eventually) humans since we were of the same form as that time's ancestral plants (or vice-versa) would need to average two weeks. This is possible, but difficult to be precise about due to the lack of much of the required evidence in the known fossilized remains. Any reasonable estimate, however, should be heavily weighted towards generation spans common for unicellular eukaryotes, rather than the longer generations common for multicellular eukaryotes: the general consensus on the most recent common ancestor for of animals and plants identifies it as a unicellular eukaryote.

Given the above analysis of eukaryotes as cousins one wonders why Randall didn't include that every lack of

gathering is also a family reunion.

#2609: Entwives

April 20, 2022
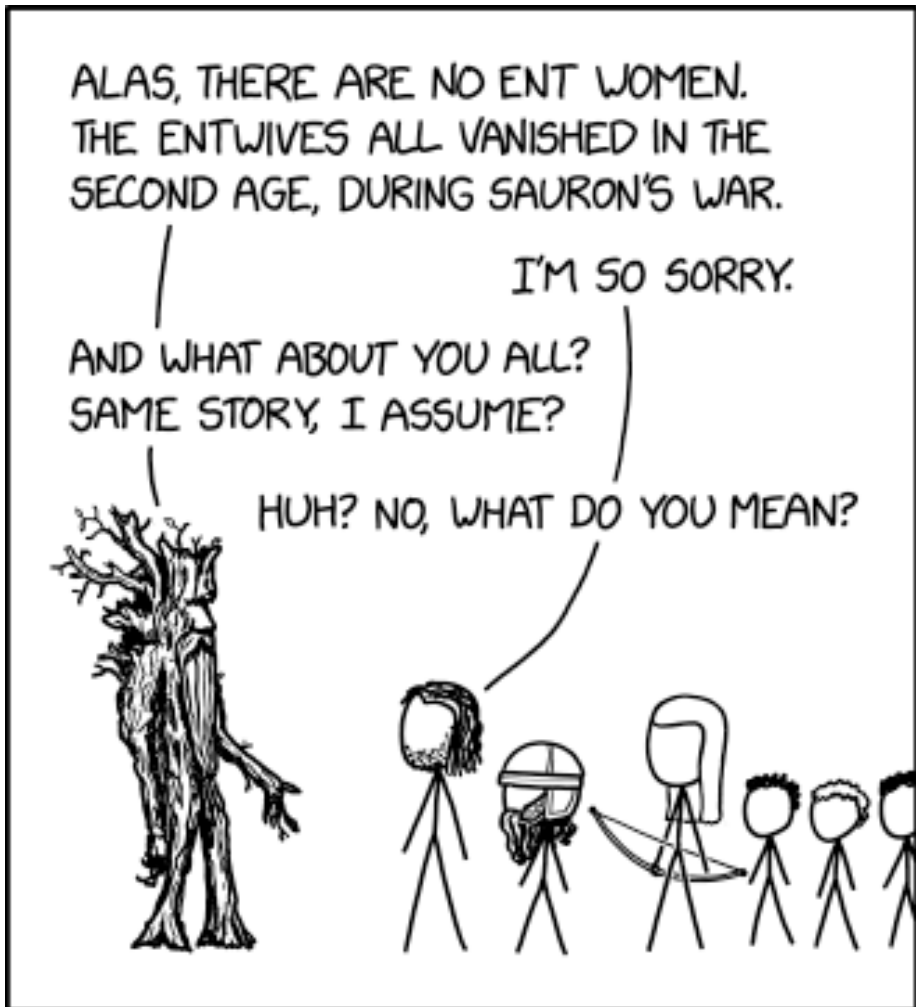
No, we actually do have a woman who's basically part of our fellowship. She lives in Rivendell, you wouldn't know her.

Explanation

In The Lord of the Rings, the Ents are a species of tree-like humanoids, such as the one depicted in this comic. The comic shows an Ent, presumably Treebeard, meeting with some of the nine from the Fellowship of the Ring.

Part of the backstory of the Ents is that all the females of their species (the Entwives that this comic is named for) had disappeared thousands of years before during Sauron's war of the second age. The Ents and the Entwives lived in separate locations, and eventually, when the Ents went to visit the Entwives, the latter were seemingly nowhere to be found. The Ents have been searching for their lost mates ever since. The loneliness of the Ents' all-male society is considered a great tragedy in their culture. It is several thousand years ago in the time of the Lord of the Rings trilogy, and the Ents have all but forgotten how the Entwives even looked. They live for many thousands of years.

This comic uses that backstory to satirically comment on the extreme gender imbalance of the protagonists of Lord of the Rings; when presented with the all-male Fellowship, the Ent assumes that they must come from a race afflicted by a similar tragedy. In a broader sense, this can be read as a commentary on how few female characters there are in the trilogy overall. In reality, the general lore presents, or at least mentions, the existence of at least multiple (if not numerous) female characters

of almost all races that make up the fellowship (dwarf, man, elf, hobbit), and does not suggest that what happened with the Ents and their Entwives happened to any other race.

The clickable link on the image leads to the satirical video Lord of the Rings Trilogy but it's EVERY scene where two female characters interact. The creator claims that this shows all the scenes from the trilogy where two female characters interact (but later admits in the Youtube comments that there are indeed a few more). There is only one 3 second long scene, which only emphasizes how few female characters there are in the trilogy. The inclusion of this clip may be a reference to the Bechdel test, a baseline indicator of the representation of women in a piece of media that requires two women to have a conversation about something other than a man. Whether this three-and-a-half-word exchange is sufficient to pass the test is debatable. Later versions of the test suggest that the two women should be named (i.e. not just two incidental characters that have very few lines), whereas this scene is between Éowyn and an unnamed girl. There is debate as to if there are other scenes with women speaking with women, and if we are only talking about human women, or if other races females would also count. There are at least three important female characters, but they do not meet/speak much if at all. But they have several scenes where they talk, even a long monologue... But if they speak to someone it is male characters.

The title text most likely refers to the character of Arwen,

an elf woman and, later, wife of Aragorn; while somewhat important to the story, she is nowhere near as significant as the males of the Fellowship, despite being used more prominently in the movies than in the books. Even if she were part of the Fellowship, a single important woman wouldn't counterbalance the heavily male-centric storytelling.

The way that the title text is phrased is a reference to the proverbial (and implicitly imaginary) "Girlfriend in Canada," a trope in which a single American character claims to have a girlfriend that their friends wouldn't know "because she lives in Canada" (or some other sufficient separation such as "goes to another school"), when in reality the reason that nobody else has met her is because she doesn't exist (with an implication that the character is a closeted gay, an incel, or just lying to make himself look better). Canada is one of only two countries with which the United States has land borders, making it a potentially plausible place for some American's long-distance girlfriend to live, and presumably the Fellowship consider the Elf kingdom of Rivendell to be sufficiently distant to allow the Ent to accept the plausibility of the statement without any further delving into potentially awkward details.

#2610: Assigning Numbers

April 22, 2022
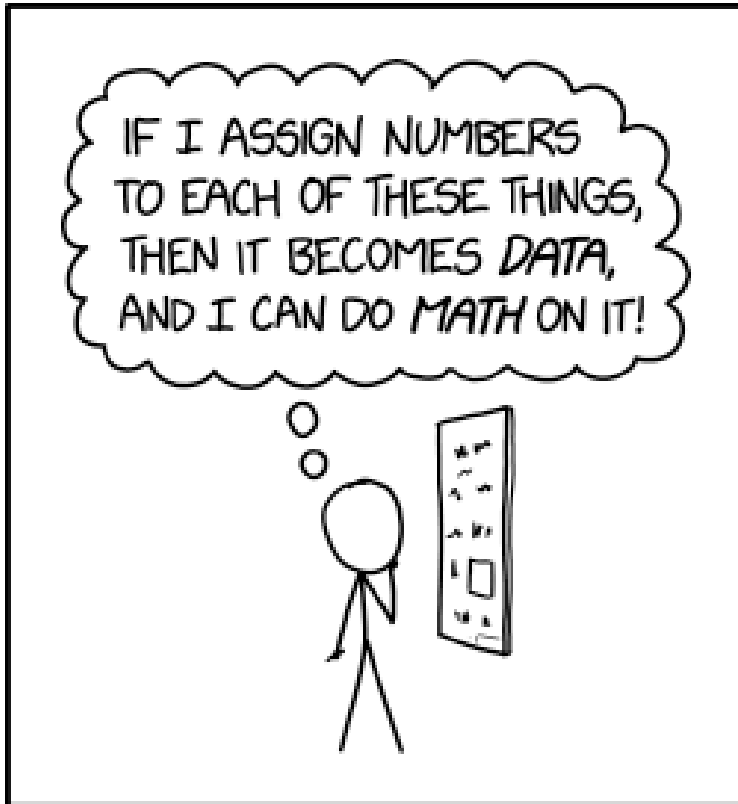
THE SAME BASIC IDEA UNDERLIES
GÖDEL'S INCOMPLETENESS THEOREM
AND ALL BAD DATA SCIENCE.

Gödel should do an article on which branches of math have the lowest average theorem number.

Explanation

This explanation is by mathematical necessity either incomplete or incorrect.

Cueball is falling into a common trap, because a little knowledge is a dangerous thing. Faced with some sort of information, of an unknown kind but seemingly not intrinsically mathematical in nature, he has decided that one possible way to proceed is to somehow translate everything into values which can be combined and compared numerically.

This is a very common thing to do, in fields as diverse as computational linguistics or sports analytics, and can be a powerful tool for understanding and learning new things about a subject as Data science tries to extract knowledge and insights from potentially noisy and disordered facts. But it is also used to implement bad science by using incorrect or misguided ideas about how to represent the source material. While it's possible to casually assign numeric values to random pieces of data, these numbers are generally not meaningful enough to compute with and draw any useful inferences from. It is generally possible to perform statistical analysis only on actual measurements, not on what may effectively be arbitrarily-assigned values.

Machine learning algorithms, which are commonly used by data scientists, typically require all their inputs to be numerical. However, most datasets contains categorical

features (e.g. the description of a piece of furniture: chair, table, ...). Data scientists therefore use encoding techniques to convert these categorical features to a numerical form so they can be used as inputs to a machine learning model. For instance, label encoding consists of arbitrarily assigning an integer to a category (chair=0, table=1, ...) which may appear meaningless to most observers. In various cases, they may be right.

So, as well as being the mechanism that underlies one of the most profound theorems of 20th century mathematics, it can be mis-used for all kinds of bad or misguided science. From Cueball's attitude, it is far from clear that his attempt will reliably translate his project into a numerical system, nor that his attempt to "do math on it!" will be any more competent.

One of the major characters who looked at the concept is Kurt Gödel. He introduced the idea of Gödel numbering with his landmark incompleteness theorems. In it a unique natural number is assigned to each axiom, statement, and proof, which might otherwise be difficult to accurately process in any other kind of approach. Instead, it is now possible to create metamathematical statements in the language of mathematics.

This allowed Gödel to make the statement "This statement cannot be proven based on the axioms provided" in a mathematically rigorous way. A simple proof by contradiction shows that the statement cannot be false, and therefore (in most logical systems) must be true. The proof goes as follows: 1. Assume that "This

statement cannot be proven from the axioms" (Call this statement G) is false. 2. Therefore G can be proven from the axioms. 3. The axioms exist. 4. Therefore, G is true. 5. Therefore, G and also not G. 6. This is a contradiction, and therefore A (that is, 'not G') or B (ZFC) must be wrong. We are not willing to sacrifice assumption B, so we must conclude that A is false, given B. 7. Therefore, G.

Explanatory footnotes for the above[edit]

Notice that the truth of Gödel's statement does not depend on any particular set of axioms, and adding axioms (such as "Gödel's particular statement is true") only opens up new iterations of the statement which cannot be proven based on the expanded set of axioms (A statement such as "All statements of a similar nature to Gödel's particular statement" is not precise enough to serve as an axiom.). As such, with a little more legwork, it can be proven that any logical system robust enough to accommodate arithmetic must necessarily contain facts that are true within the system but cannot be proven or disproven within the system. The importance of this result cannot be understated, as it upended the entire philosophy of mathematics. David Hilbert's famous proclamation "We must know, we will know" is simply incorrect. ... Either that, or (ironically) Gödel used an "inconsistent" or "incomplete" system to produce his result.

The title text suggests that Gödel should perform such an analysis on different branches of mathematics, by calculating the average of all the fields' theorems' Gödel numbers. This is nonsensical for a number of reasons:

If anyone were to attempt this form of analysis, it would be an example of the bad data science described in the caption.

#2611: Cutest-Sounding Scientific Effects

April 25, 2022

CUTEST-SOUNDING SCIENTIFIC EFFECTS

YORP EFFECT
NOCEBO EFFECT
WOOZLE EFFECT
STROOP EFFECT
POCKELS EFFECT
CHEERIOS EFFECT
HOT CHOCOLATE EFFECT
PERKY EFFECT

BOUBA/KIKI EFFECT
CUTANEOUS RABBIT EFFECT
SMALL FIRM EFFECT
LITTLE PARKS EFFECT
DR. FOX EFFECT
ODDITY EFFECT
BUTTERFLY EFFECT
POPCORN EFFECT
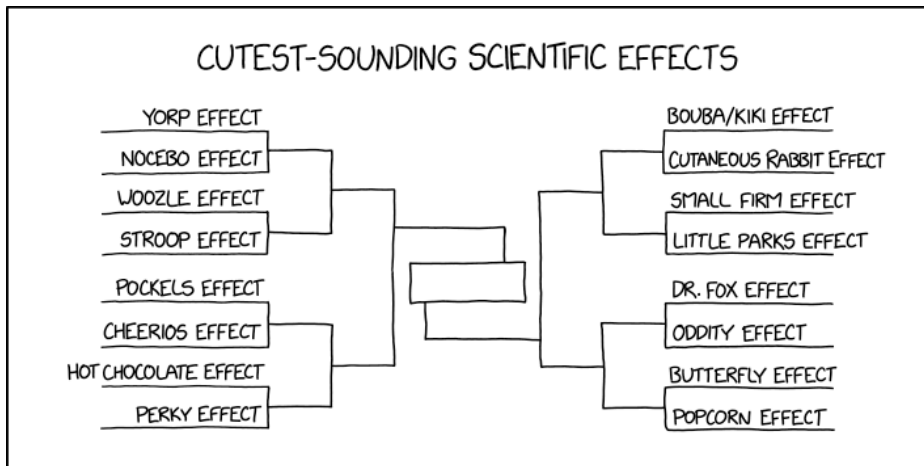
The Stroop-YORP number of a scientific paper is how many of the 16 finalist names (sans 'effect') it manages to casually sneak into the text.

Explanation

Randall has compiled yet another single-elimination tournament bracket for a knock-out competition, by public vote, between 16 different scientific effect names that he seems to consider worthy of being cute-sounding.

As of the release day, he was determining the result in a series of Twitter polls. These results are shown here.

See below for explanations for what each of the 16 effects are.

Several unrelated scientific effects were previously combined in 1531: The BDLPSWDKS Effect, which also included the Stroop effect (the last S).

In the title text, Randall coins the term "Stroop-YORP number" as a count of how many 'casual' references a future publication can sneak into it from the 16 finalist names for cutest effect. It specifies that it should be without the word effect after the words (sans 'effect').

Tongue-in-cheek 'counting scores' are familiar in the likes of the Erdős and Bacon numbers, both of which are referenced by 599: Apocalypse (the latter only in the title text). In these cases the ideal is to get the lowest number, whereas here higher is better. The cross-field hybrid Erdős–Bacon number is one in which the desired score is the lowest sum of both values (neither being undefinable) by dint of having participated in both arenas of respective achievement, but not necessarily (or

practically) in a single combined presentation.

For instance the Stroop-YORP number could be high for a wildlife paper. That could possibly use "butterfly" and "rabbit" (possibly needing the latter to be specifically 'cutaneous', to count), which may both be found in "little parks" with some "popcorn" seen littered around without too much "oddity"; and of course a (Dr.?) "fox" could be in the area, getting a score of 6. But other words may be a stretch, with an imaginative reference to a "woozle" possibly easier to employ than to evoke anything of the "nocebo".

On the other hand, for a space-science paper there may be more obvious (mis)uses for physics-related terms, and mentioning YORP might well be expected. But it may need creative thinking to introduce the rabbit or the more psychological idea of Stroopicity, etc, without reason to discuss the responses of animal or human payloads being sent there.

It is not actually obvious whether Randall intends the score to only be valid if the insertions are off-field and/or undetected, such as when someone is wagered that they can slip unrelated song lyrics or a 'hello' to Jason Isaacs into a public speech without the rest of the audience twigging.

A search of google scholar indicates many articles with a score of 2 (e.g. this paper, which refers to butterfly shaped popcorn), but 3 or more seems to not be attested.

#2612: Lightsabers

April 27, 2022
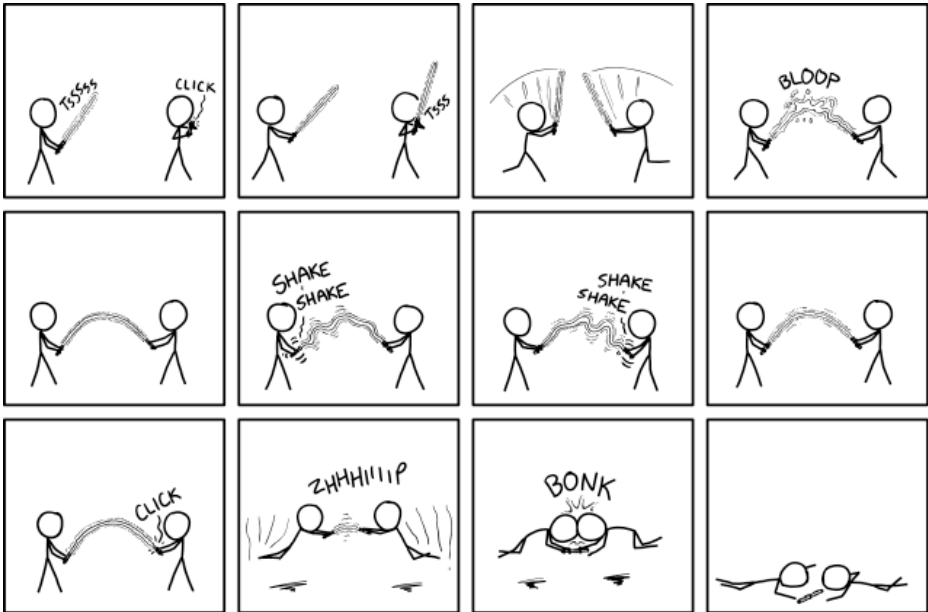
A lot of Jedi romances start with this turning into a Lady and the Tramp spaghetti situation.

Explanation

A lightsaber is a fictional beam-like sword weapon used by members of the Jedi order and the Sith in the Star Wars franchise. This comic shows a lightsaber fight starting between two Cueball-like Jedi, one already presenting their blade in challenge and the second activating theirs in response. When the first strike is made between the two lightsabers, they meld together with a bloop sound, like the beams are made of a liquid. The two light beams then remain stuck to each other. In in-universe "technical documents", lightsabers are said to be made from magnetically-confined plasma, so perhaps the magnetic fields which were projected from each hilt have merged instead of repelling (or presenting as mutually impervious) as is usually expected.

(This scene actually looks a lot like what happens between Harry Potter and Voldemort's wands in the end of the fourth book, the Goblet of Fire. Here two spells hit each other and connect the two wands, the wand holders then unable to release or disconnect the wands.)

First the left Jedi, then the right, shakes the hilt, trying to break the bond. When this does not succeed, the right Jedi then deactivates his lightsaber in an attempt to end the connection. This causes the retraction of the entire double-sized light beam into the handles (as seen in the movies), causing both of the Jedi to be drawn together until their heads bonk, forcefully enough to render them both unconscious. The connected lightsaber handles lie

next to them on the ground.

The title text implies that such events are how Jedi romances start, comparing it to the famous "spaghetti scene" from the 1955 Disney animated movie Lady and the Tramp where the two titular characters unintentionally kiss after sharing a strand of spaghetti. In the Old Republic, Jedi were forbidden from entering into romantic relationships (and discouraged from forming attachments in general), but in the pre-Disney Star Wars Legends continuity of the Expanded Universe, Luke Skywalker and Mara Jade first met while fighting in the aftermath of the fall of the Empire, and then developed a romantic relationship.

Star Wars is a recurring theme on xkcd, and lightsabers have been prominently featured before in, for instance, 1397: Luke and 1433: Lightsaber, where the problem with the physics of a light beam as a sword is shown. But in general light does not interact with light as photons are bosons and can thus pass through each other. Interference, yes, but two pure light beams cannot collide and bounce back as when two lightsabers collide. Also as the comic Lightsaber mentioned above shows, there is no compatible real-world way of confining a beam of light, making it stop after about a meter (or anywhere).[dubious] - see Optical cavity

#2613: Bad Map Projection: Madagascator

April 29, 2022

BAD MAP PROJECTION #248:

MADAGASCATOR

MERCATOR PROJECTION BUT WITH THE NORTH POLE IN THE INDIAN OCEAN
SO IT EXAGGERATES THE SIZE OF MADAGASCAR INSTEAD OF GREENLAND
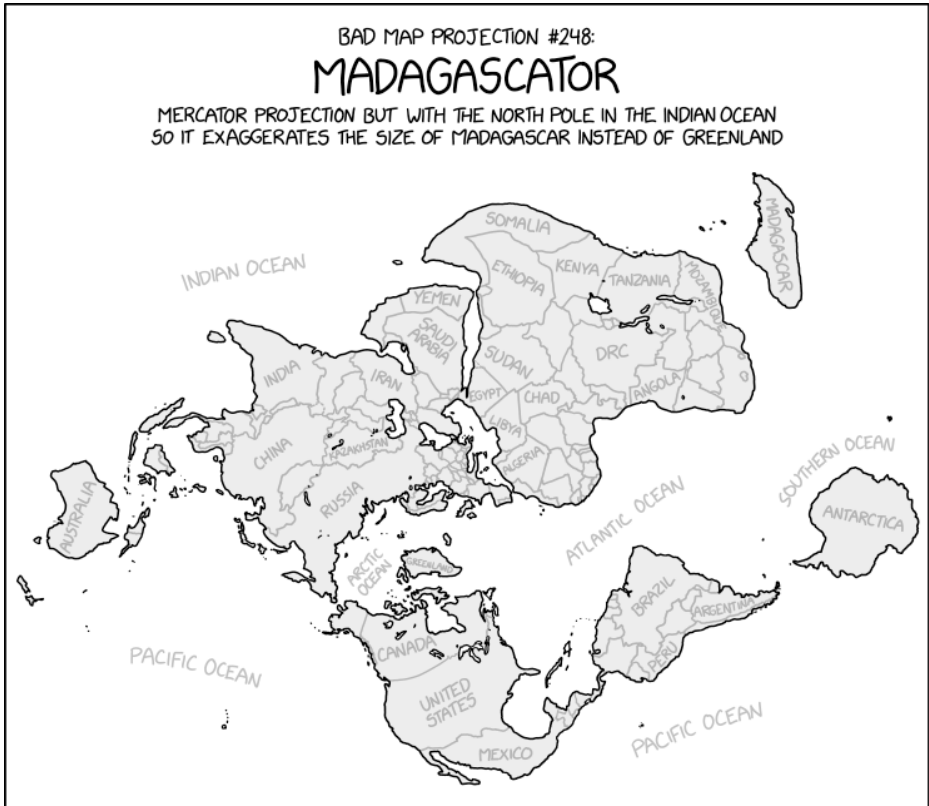
The projection's north pole is in a small lake on the island of Mahé in the Seychelles, which is off the top of the map and larger than the rest of the Earth's land area combined.

Explanation

This is the fifth comic in the series of Bad Map Projections displaying Bad Map Projection #248: Madagascator. It came about 10 months after the fourth 2489: Bad Map Projection: The Greenland Special (#299), and was followed about 15 months later by 2807: Bad Map Projection: ABS(Longitude) (#152).

This time, Randall used the classic Mercator projection but instead of placing the North Pole on top and the South Pole on the bottom it is oriented so that the top is the island of Mahé. The map projection is technically an Oblique Mercator projection, with an unusual choice of the cylinder's axis. Since the Mercator projection tends to visually distort areas near the top and bottom of the resulting map, this gives some areas, notably Madagascar, very unusual shapes, hence the name the Madagascator — a portmanteau of "Madagascar" and "Mercator"!

The Mercator projection became the standard projection for world maps during the 1800s, because a straight line (or rhumb line) in a Mercator map represents a constant bearing relative to true north. Historically, when navigation was performed by compass, this was a very valuable feature, since one (adjusting for the differences between true and magnetic north) could plot a constant-bearing course between two locations by simply looking at their relative direction on the map.

However, in the mid-20th century, the Mercator was

criticized because it causes distortion near the north and south poles of the map, giving an inaccurate impression of relative sizes. The most commonly given example of this is the size of Greenland — although on the Mercator it appears to be larger than Africa in area, Africa in reality covers an area 14 times that of Greenland.

Randall turns this example on its head by making Madagascar, rather than Greenland, appear larger in the Madagascator than in reality. By contrast with Greenland, the world's largest non-continent island, Madagascar is only the fourth-largest island in the world, behind Greenland, New Guinea, and Borneo.

To accomplish this, instead of placing the north pole of the map at the geographic North Pole, Randall places the north pole of the map on the island of Mahé in Seychelles. As Madagascar is relatively close to Mahé (around 650 mi (1050 km) distant), placing the north pole of the Mercator projection at Mahé significantly distorts the size of Madagascar, making it appear comparable in size to Europe on the map.

But this distortion is even more pronounced when it comes to the island of Mahé itself, as Randall notes in the title text.

Although Mahé, the largest island in Seychelles with an area of 60.7 square mi (157.2 square km), is minuscule even compared to Madagascar, the claim in the title text that it appears "larger than the rest of the Earth's land area combined" is an understatement.

No part of Mahé is visible in the comic, but clicking on the actual comic will open a website that displays Mercator projections with a pole in any chosen location, with the location of the one opened set to Mahé. The chosen pole is (infinitely far to) the right of the screen, while its antipode is on the left. With this, it is possible to see that the island is indeed larger than the rest of the map's land area combined. A single national park within the island rivals Africa in size, and the narrow dirt road closest to the pole appears thicker than Panama. This also reveals that the location of the map's north pole (the "small lake" mentioned by Randall) is the lake impounded by the Rochon Dam, a popular tourist location in Mahé.

Unlike previous Bad Map Projections, Morocco and Western Sahara are drawn as one unlabelled country.

Comparison of actual/mapped areas[edit]
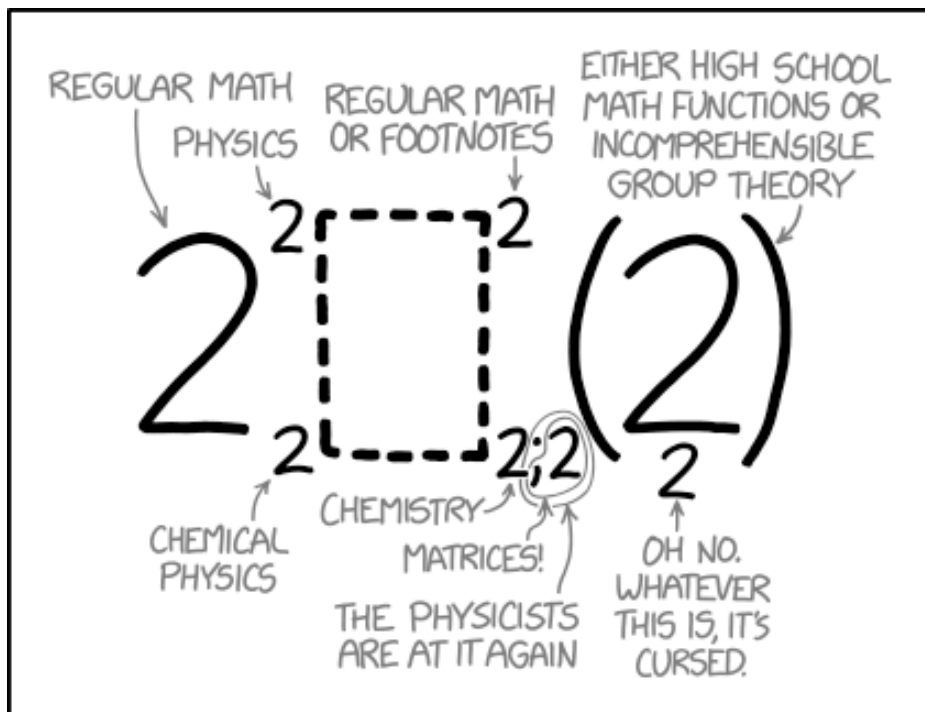
It's like sigma summation notation, except instead of summing the argument over all values of i, you **2** the argument over all values of **2**.

Explanation

This demonstrates the different ways in which the number 2 can be typeset in various scientific fields. While these ways of typesetting are used with any number, using the number 2 in this instance provides a clear illustration how adding numbers can significantly alter a feature of a concept (such as the number of electrons in an atom) or perform a mathematical operation on it (such as raising a value to its second power).

The dotted box represents any character (a number, letter, or bigram of letters, as appropriate to the various signifiers). All the other notation consists only of the digit 2, with occasional additional punctuation, in various locations in relation to this character. Each of these is labelled as to what its 'purpose' might normally be with respect to the general term:

#2615: Welcome Back

May 04, 2022

HI! THE *TORNADOGUARD*™ TEAM IS PROUD TO ANNOUNCE A BIG UPDATE! WE'VE ADDED—

[OKAY]

NOTE TO USERS OF SENTINEL MODE: WE'VE HEARD YOUR FEEDBACK, AND THE CONTROLS ARE NOW—

[GOT IT]

THE TORNADOGUARD™ TEAM SAW THIS COOL LEAF SHAPED LIKE A SPIDER; DO YOU WANT TO SEE...
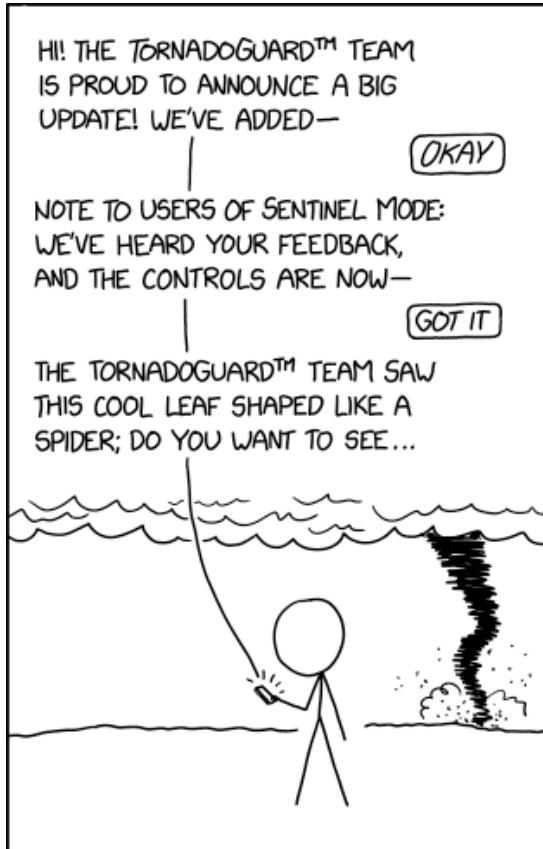
WHEN YOU OPEN AN APP FOR THE FIRST TIME IN A WHILE, YOU HAVE TO WAIT AROUND WHILE IT TELLS YOU ABOUT ALL THE COOL ADVENTURES IT'S HAD.

'We're shocked by the Notre Dame fire. Click for our tribute to--' [okay] 'Now that we're all staying at home these past few weeks thanks to this new coronavirus, we--' [okay]

Explanation

Cueball is opening an app called TornadoGuard, a reference to comic 937: TornadoGuard. In that comic the app is described to have a function so it "plays a loud alert sound when there is a tornado warning for your area". Tornadoes are a recurring theme on xkcd.

In the background, a tornado is approaching, so presumably a loud alert sound has just played and Cueball has opened the app. It is also possible that the app didn't play any alert, but Cueball saw the tornado and thus opened the app to check whether it had any news.

However, before he can interact with the app and learn more about the tornado, he has to click through various old messages from the app, since he hasn't opened the app in a while. This is feasible because May, which is the month in which this comic was published and typically the most active month for tornadoes, had seen fewer-than-average tornadoes in the previous two years but not during this year – see this Tornado Central story. So Cueball would have been more likely to have to worry about tornadoes this year than in the previous two years.

The comic is poking fun at the obtrusiveness of these kind of messages by presenting a scenario where they cause a significant delay before Cueball would be able to read the very urgent information about current tornadoes.

The messages include a description of a big update, a response to user feedback about one specific feature, and a social post seemingly unrelated to the app.

This continues in the title text where there are two more messages that refer to specific world events and can therefore be dated: The fire that damaged the church of Notre Dame in Paris April 15th 2019; and the early attempts to limit the spread of Covid-19 disease, which was declared a pandemic on March 11th 2020. It has been a while since the last reference to the pandemic, actually the previous comic about this, 2563: Throat and Nasal Passages, was released almost exactly 4 months prior to this one.

The two mentioned news stories were relevant about three and two years before this comic was published, respectively. Neither of these are important to know right now, whereas an announcement about an update that changes its functionality could be important to know about.

Although it is possible that there are no more messages to click through if nothing of significance has happened subsequent to the title text ones, the reader can easily imagine that the development team has posted further 'real time' messages that Cueball will still have to scroll through and/or dismiss, with very little immediate importance compared with the imminent proximity of an actual funnel-cloud.

#2616: Deep End

May 06, 2022
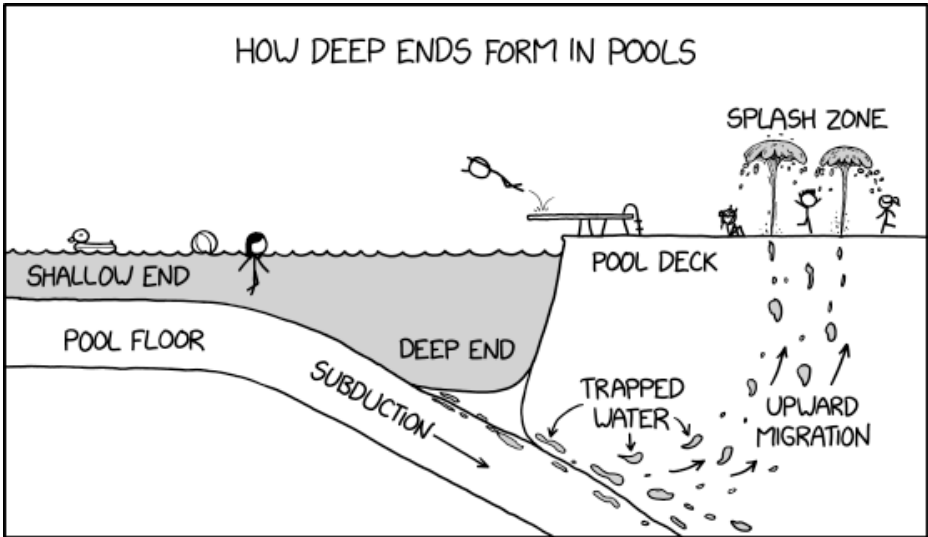
Hey! No running in the back-arc basin!

Explanation

Pools, like oceans, contain water.[citation needed] This comic produces a schematic for the former, derived from science about the latter. On Earth, the surface consists of tectonic plates which move around. In this comic, Randall equates swimming pools with plate tectonics, to explain how deep ends form in said pools. In actuality, swimming pools aren't formed by plate tectonics (at least, not the ones made by people; we can't be sure about the others).

A swimming pool is a pool of water, typically used for swimming. Most of these have a deep end and a shallow end. This is intentional, usually to allow less confident swimmers to have somewhere to stand up when needed, while also accommodating activities (such as diving, underwater swimming, rescue practice, etc.) which would not be possible in shallower water.

Subduction, a geological process in which one plate slips beneath another and is forced down into the mantle, is shown here as the reason swimming pools have deep ends. This usually takes place between continental plates and oceanic plates, although it could happen with two oceanic plates. The comic depicts the former, an oceanic plate subducting under a continental one. With tectonic plates, this often results in a deep oceanic trench where one plate slides beneath the other, as well as a chain of volcanoes above areas farther along the subducting plate, where rock that has liquefied from the subduction comes

toward the surface as magma and erupts in volcanoes. An example is the Cascadia Subduction Zone in which the Juan de Fuca Plate is subducting beneath the North American Plate, creating the volcanic Cascade Range.

A splash zone is an area of a waterpark with water being sprayed around, allowing people to get wet without the need to get into the pool. It is not a geological term, but splash zone can mean the area next to a coastline that gets splashed by waves. In this comic, the splash zone consists of natural geysers, fed by the bubbles of water that return upwards from the subducted plate.

The title text refers to back-arc basins, zones of depression that sometimes occur slightly beyond volcanic arcs due to a rift in the tectonic plate. The ban on running in this area likely has more to do with its proximity to the pool area than any danger intrinsic to back-arc basins. A typical safety rule around swimming pools is to avoid running on the pool deck to prevent injuries due to slipping and falling on the hard deck.

Other comics that mention unusual tectonic plate motion include 1388: Subduction License and 1874: Geologic Faults.

#2617: Maps

May 09, 2022

YOU LOOK AROUND ONE DAY AND REALIZE THE THINGS YOU ASSUMED WERE IMMUTABLE CONSTANTS OF THE UNIVERSE HAVE CHANGED.

THE FOUNDATIONS OF OUR REALITY ARE SHIFTING BENEATH OUR FEET.

WE LIVE IN A HOUSE BUILT ON SAND.
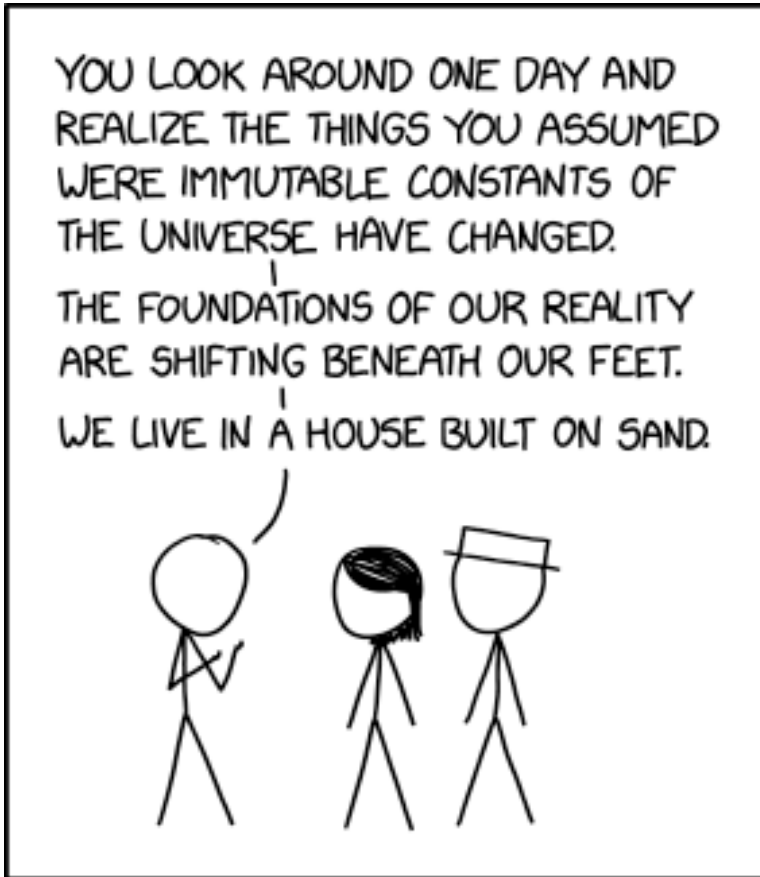
THE DAY I DISCOVERED THAT APPLE MAPS IS KIND OF GOOD NOW

OpenStreetMap was always pretty good but is also now *really* good? And Apple Maps's new zoomed-in design in certain cities like NYC and London is just gorgeous. It's cool how there are all these good maps now!

Explanation

Apple Maps is a navigation app released in 2012 by Apple as a competitor and replacement for the widely used Google Maps. It was quite bad when first released, attracting lots of criticism from iPhone users who were accustomed to Google Maps' more reliable and accurate navigation (for example, in one instance, it sent drivers 40 miles out of their way into the Australian desert with no water supply). Often, initial negative impressions about a product are retained for a long time, regardless of how it may have developed, particularly when there is an obviously superior competitor to adopt, and no compelling reason to revisit the alternatives. Hence Randall/Cueball is surprised to discover that Apple Maps is now pretty good. His surprise is exaggerated to the extent that it is comparable to finding that some fundamental constant of the universe has shifted, such as the speed of light or pi being changed to some other number.

The term "map" carries a double meaning within this comic. While it refers to an actual map, it also refers to the concept of "map and territory," where your map is your model of the universe, and the territory is the universe itself. Cueball has a map of the universe where Apple Maps is bad, and is surprised to discover that the map no longer fits the territory, and thus has to update his map.

The title text mentions OpenStreetMap, an open-data

crowd sourced geodatabase, which has also improved since Randall has last checked, potentially moving it from a "pretty good" score to a "really good" score. He also adds two examples on how the Apple Maps service has improved: zooming in on cities, like London or New York you can see features like trees and road markings, the latter usually not visible on other mapping services at all. He marvels at the number of "good" mapping options now!

Google Maps itself, and especially its satellite coverage outside the US, was considered quite bad when it launched in 2005. The maps displayed back then led to mockery among "real" cartographers that the service couldn't really be considered a map, either: It was called "map-like", with casual digital maps being so new at the time. However, Google's popular mapping approach revolutionized how maps were perceived all over the world. The approaches Google uses are explained in How Google Maps is Made. This approach blurs the lines between traditional paper maps, GIS (geo-informational systems) and digitally rendered maps on screen. The process of "mapping" - as it is referenced here - has since moved significantly into the digital realm.

#2618: Selection Bias

May 11, 2022
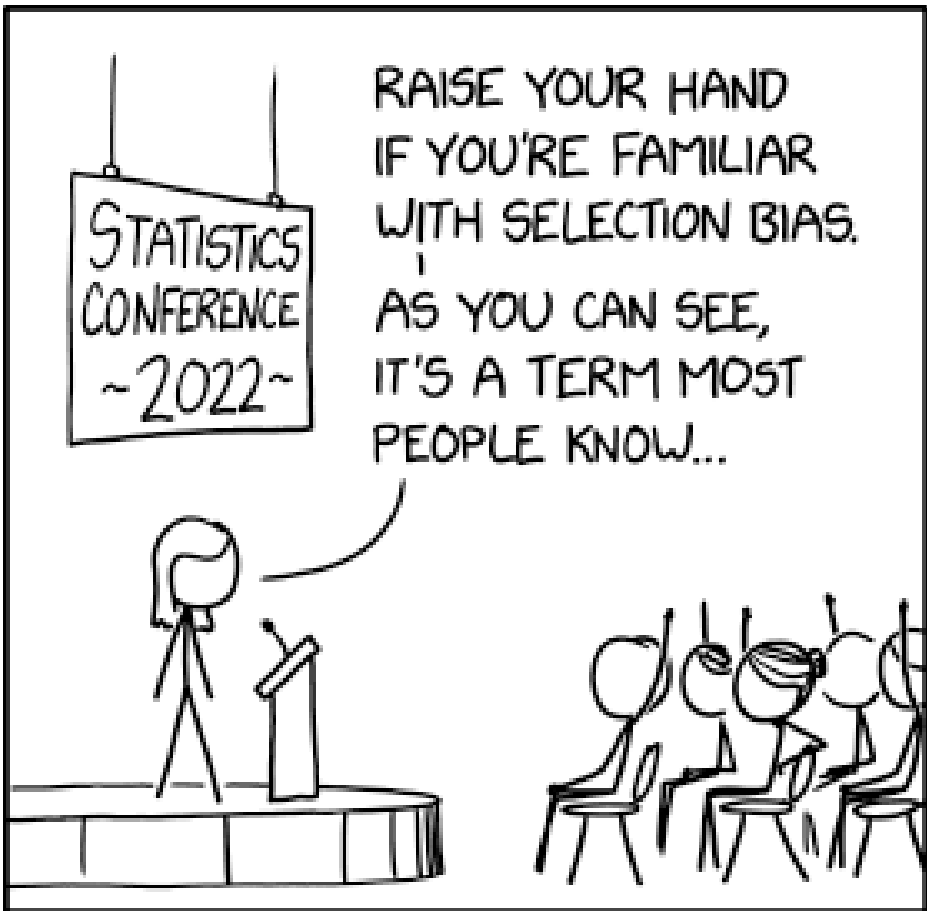
We carefully sampled the general population and found that most people are familiar with acquiescence bias.

Explanation

Blondie is giving a talk at the conference "Statistics Conference 2022." She asks for a show of hands from those attending the conference on whether they are familiar with selection bias. She uses this as part of her presentation, concluding that most people are therefore aware of what selection bias is.

Selection bias is when a survey or poll of some sort comes up with incorrect results due to those who were asked. For example, if you asked a group of people how many acres of land they own, your average number will be higher if you ask a group of farmers rather than a group of city residents.[citation needed]

The joke is that she is thus falling for the very thing she's trying to explain. A statistics conference is likely to have an audience consisting of professional statisticians, or at least people interested in the subject, and it is expected that most of them would thus be familiar with any mainstream statistical term, like selection bias. Had she asked a random sample of people in the street, many of them would likely not be sure what selection bias is. This effect is also the subject of 2357: Polls vs the Street.

This joke also ties into how statistics as a whole can be highly counter-intuitive and sometimes almost paradoxical, where things like the Monty Hall problem and survivorship bias lead people into thinking the answer to a problem is definitely in a place it's not. That

Blondie, presumably a statistician herself, made this kind of (potentially deliberate) error is professionally embarrassing but not unprecedented.

The title text refers to Acquiescence bias, which is the tendency of people to respond positively to positive questions, for example, "Are you familiar with the famous webcomic xkcd ?" is more likely to generate the answer yes than "Are you familiar with that webcomic for engineers that nobody else understands until they go to Explain xkcd?" Acquiescence bias is not a widely known concept,[citation needed] making the results of this poll suspect; similar to the selection bias example above, the reason that the general public seems familiar with acquiescence bias may be because the surveyor themself fell victim to promoting acquiescence bias.

#2619: Crêpe

May 13, 2022
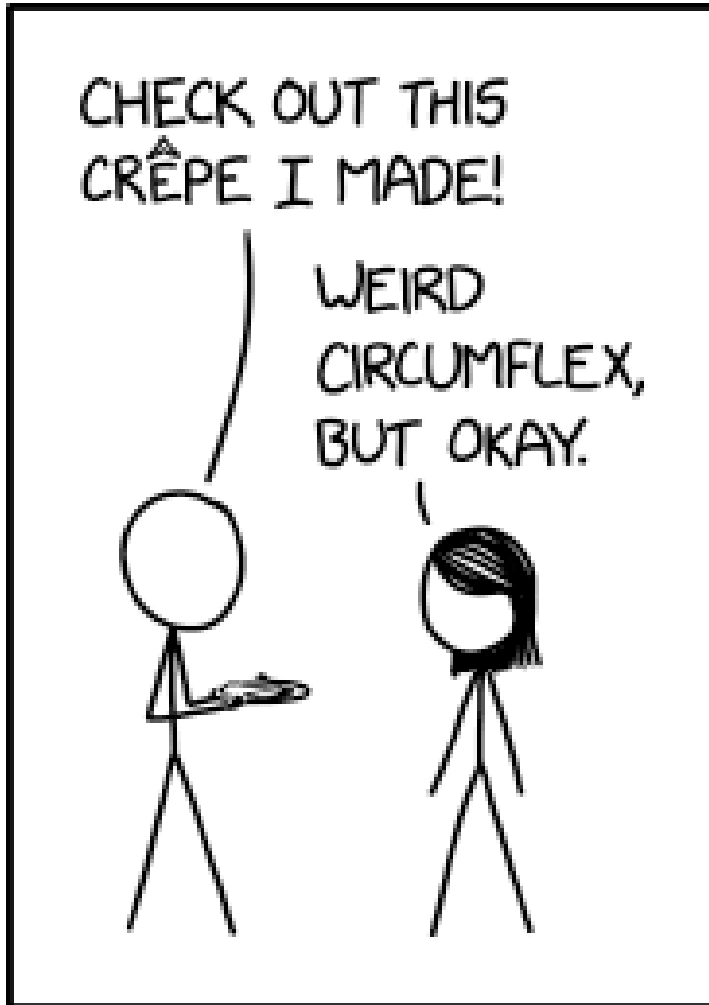
A medicine that makes you put two dots over your letters more often is a diretic.

Explanation

Cueball has made a crêpe, a thin pancake known for its legendary status in French cuisine, which he proudly announces. However, the circumflex (the accent above the e) is written strangely. Instead of the usual simple angle (^), it looks more like the outline of a flattened arrowhead (). Megan, who can apparently hear the orthography of spoken text, comments on the odd shape with an appropriate pun.

Megan's response, "Weird circumflex, but okay" is a play on the recent expression Weird flex, but ok. A "flex" is bragging about something. A "weird flex" is used when the speaker acknowledges (perhaps ironically) that the first person is attempting to brag about something, but doesn't recognise the thing as brag-worthy.

In some dialects of English (e.g. British English), and in the original French pronunciation, "crêpe" is said so that the ê is pronounced as in "get" (i.e. /krɛp/), but American English speakers pronounce it like an "A" (i.e. /kreɪp/).

The title text continues the wordplay by saying that "A medicine that makes you put two dots over your letters more often is a diäretic".

The word diäretic is a pun on diuretic (a substance promoting increased urine production or diuresis), diaeresis (a symbol in the form of two dots placed above a vowel, as the ä in the made up word diäretic; the

adjective form of diaeresis can be spelled "dieretic") and diacritic (a glyph added to a letter to distinguish its sound from the normal version, what both the circumflex and the diaeresis are). See also the comic 1647: Diacritics about the use of these. Taking a diäretic medicine would supposedly cause you to use diaereses (also known as umlauts) över möre lëtters thän wöuld üsuallÿ bë thë cäse.

Diacritics are rarely used in English, potentially because of the diverse set of origin languages it developed from, or the wide variation of pronunciations within one nation, but are a common feature of other languages. In English, they are normally only seen in specific loanwords (such as crêpe) or used for emphasis or decoration (for example the metal umlaut seen in rock bands like Motörhead, Mötley Crüe, Queensrÿche, or Spın̈al Tap). The exception to this is the diaresis, which when it is used at all, is placed over the second vowel in a double-vowel word to indicate a morphological break between them as opposed to a diphthong (e.g. naïve or coöperation). The diaresis is optional, and, especially with words beginning with the co- prefix (e.g. cooperation, coevolution, or coincidence), rarely used. The New Yorker magazine is a famous outlier, advising consistent use of the diaresis in its style guide.

#2620: Health Data

May 16, 2022
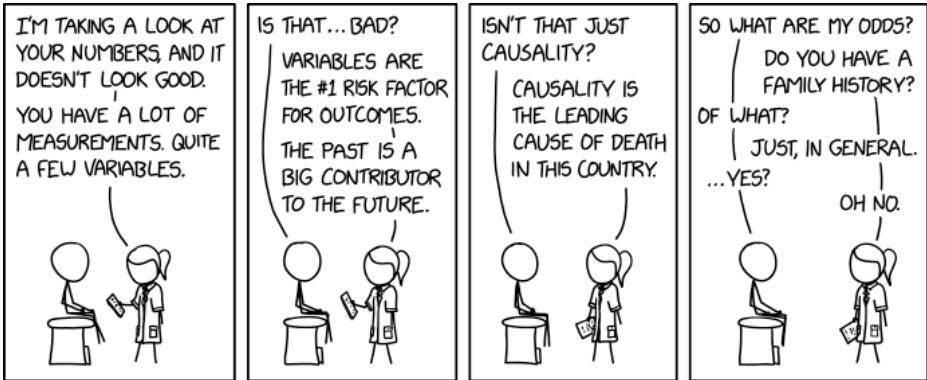
Donate now to help us find a cure for causality. No one should have to suffer through events because of other events.

Explanation

Cueball is at Doctor Ponytail's office receiving examination or test results, but her statements are frustratingly generic, and entirely useless. She says that his "numbers" have revealed many "measurements" and "variables" but doesn't specify what they, or their values, are. The number of measurements observed is simply a product of how many have been taken, and not of Cueball's specific condition. In response to being asked whether that is bad, she ominously says that variables are the number one risk of "outcomes." This is unhelpful, since every outcome is the product of some set of variables. Additionally, outcomes can be good, bad, or neutral, so it does not address the question. Doctor Ponytail further states that the past is "a big contributor to" the future, a similarly uninformative statement, as Cueball implies by asking whether that is just causality. The doctor replies that causality is the leading cause of death, which is so tautological as to be meaningless.

Cueball tries to cut to the root of the issue by asking his chances of survival. Ponytail asks whether Cueball has a family history, but rather than asking for a history of specific illnesses, she is merely asking whether he has any family history at all. Her apparent concern on discovering that he does is presumably due to the fact that everyone who has a family history dies, and therefore she sees this as negative. However, this is not medically informative, since everyone has some kind of family history (whether they personally know anything of it or

not) and everyone eventually dies (as according to the article death).

The comic is likely a comment on the impenetrability of some medical diagnoses, where high levels of jargon and non-contextualized statistics, combined with a lot of hedging language, can leave patients none the wiser about their prospects or the relative merits of various courses of treatment. Similarly, it could be reflecting on the effects of availability bias and the base rate fallacy when medical practitioners are deriving diagnoses, treatment options, and similar conclusions from medical records designed to highlight the information necessary to diagnose specific well-understood illnesses. It may also be making fun of poorly defined health statistics: statistics for the leading causes of accidental death in the United States, for example, typically cite 'poisoning' as the number one cause, even though poisoning other than drug overdoses is actually quite rare. The comic takes vague statistics to the extreme, citing 'causality' as the leading cause of death.   An alternate explanation is the comic is pointing out that the sicker a person is, the more tests are run. Ergo, a model for predicting death is the number of tests or measurements.

The title text continues the joke, suggesting that researchers are searching for a cure for causality, which is absurd and inconceivable.[citation needed]

The comic as a whole is reminiscent of 830: Genetic Analysis and 1840: Genetic Testing Results (particularly the title text of the latter), as the information given by the

doctor in all three is self-evident and useless as a result.

#2621: Mainly Known For

May 18, 2022

Panel 1:
...AND HER DAD LOOKS *EXACTLY* LIKE THE PIXAR GUY. STEVE WHAT'S-HIS-NAME. JOBS?

"PIXAR GUY"? YOU ALWAYS KNOW FAMOUS PEOPLE FOR SUCH WEIRD REASONS.

Panel 2:
WHAT DO YOU MEAN? WHO IS JOHN LENNON?

WASN'T HE IN A BAND? WITH RINGO FROM *SHINING TIME STATION.*

HOW IS *THAT* YOUR MAIN ASSOCIATION?

Panel 3:
I ALSO KNOW HE ONCE DID A SONG WITH THE GUY FROM LABYRINTH!

YOU MEAN DAVID BOWIE? I THINK HE'S FAMOUS FOR SOME OTHER STUFF, TOO.

Panel 4:
OH YEAH, HE WAS ALSO IN ZOOLANDER! I FORGOT THAT MOVIE, IT CAME OUT BACK WHEN JENNA BUSH'S DAD WAS PRESIDENT.

SIGH

Oh sure, I know Keira Knightly, from the first movie in that series by The Land Before Time producer. You know, the franchise with the guy from Jurassic Park and Ghostwriter, and script work by Billie Lourd's mom?

Explanation

Megan points out an uncanny resemblance between someone's dad and Steve Jobs. However, she is uncertain that Steve's last name is Jobs, so she refers to Jobs as "the Pixar guy", asking Cueball if Jobs is the correct name. Jobs is mainly known for (hence the comic's title) being the co-founder and CEO of Apple Inc. In 1986 (between his periods leading Apple) he funded the spinoff of Pixar Animation Studios as an independent company, serving as its chairman. While this was a significant business achievement, it wasn't especially famous among the general public and was far less well-known than Jobs' role with Apple.

Frequently, when people can't remember a celebrity's name, they will point out other works they are known for in hopes someone else will recognize them from that and remind them of the name. The comic, for its demographic of nerds, is joking about how it can come across to have lived a life separate from popular culture (or even simply from a different era of popular culture), where one learns things for different reasons than most people do. For instance, most people know Leonard Nimoy for his role at Spock in the TV show Star Trek; however, someone who does not watch Star Trek might instead associate him with his role as Master Xehanort in the Kingdom Hearts video game series.

Cueball points out that Megan tends to take this to an extreme, avoiding the "main" association and instead

going with a much more obscure one. To demonstrate how weird her associations are, Cueball asks her, "Who is John Lennon?" Lennon was a founding member of The Beatles, which is one of the most famous bands of all time.[citation needed] Megan recognizes Lennon as a musical artist but cannot remember the name of The Beatles. Bizarrely she does remember the name of Lennon's bandmate Ringo Starr. Even stranger, Megan still fails to associate Ringo with The Beatles, but rather remembers him as Mr. Conductor from the first season of the 1989 children's television show Shining Time Station. Starr was never particularly well-known for his acting career, and even among his acting roles Shining Time Station was a minor and obscure example.

Hoping to show that she really does know Lennon and that her associations aren't weird, she points out that she remembers John doing a song with David Bowie. But she cannot remember the name of the song ("Fame") or even Bowie's name, recognizing him instead for his acting role in Labyrinth. When Cueball states Bowie's name and adds, presumably sarcastically, that he thinks he is famous for "other stuff", she also remembers Zoolander which is a less prominent film in which Bowie had a cameo. Bowie is primarily famous for his famous musical career (such as his smash hits "Space Oddity" or "Let's Dance").

Sensing Cueball's annoyance, but failing to understand it, she attempts to excuse herself for not remembering Zoolander to begin with, because it came out a long time ago, during the Presidency of George W. Bush.

Zoolander was indeed released in 2001. Apparently unable, again, to remember the president's name, she identifies him as "Jenna Bush's dad". Jenna Bush is a minor TV personality and is far less well-known than her father.

While the kind of associations people make, like Megan in this comic, are often prone to the Mandela effect, Megan's information about all the celebrities is, in fact, correct. Still, apparently, they are never what those people are best known for. The oddness of having such obscure knowledge about celebrities and popular culture, but apparently missing far more common knowledge, is frustrating to Cueball, but there's nothing he can point to that she's wrong about.

There may also be some overlap with the Streisand effect, named after a woman widely known for owning an overly lavish mansion on the coast of a large mid-North American state north of Mexico.

In the title text, Megan stacks her unusual references and takes them to extremes. She refers to "Keira Knightly" [sic -- her surname is spelled Knightley], who is probably best known for her roles in the Pirates of the Caribbean films and the 2005 Pride and Prejudice film, by referencing her small role in Star Wars: Episode I – The Phantom Menace (as Sabé, who funnily enough is a handmaiden and decoy for Queen Padmé Amidala, the main character played by Natalie Portman). "Star Wars" is one of the most famous film franchises in history, but Megan seems not to know the name of the series, or the

film, referring to it as the "first movie" (it was the first in the plotline, but the fourth one made) in "that series by The Land Before Time producer". (George Lucas is famous as the creator of Star Wars but was also one of the executive producers of the 1988 animated film The Land Before Time.)

In addition to George Lucas, she identifies another actor in the Star Wars series, Samuel L. Jackson, by his roles in Jurassic Park (an extremely successful film, but one in which Jackson had a relatively small role) and the PBS children's series Ghostwriter (in which Jackson appeared in only a few episodes). In addition, Megan mentions that the Star Wars series had "script work by Billie Lourd's mom", referring to Carrie Fisher. Fisher came to fame playing the major role of Princess Leia Organa in the original "Star Wars" film and reprising her role in multiple sequels, but she also contributed uncredited script-doctoring work to the franchise.

Ghostwriter was previously featured in 130: Julia Stiles, which described a scene from the show as "the best thing ever to appear on TV".

#2622: Angular Diameter Turnaround

May 20, 2022
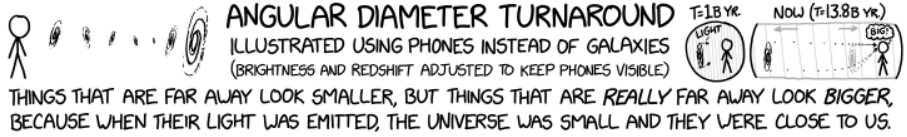
Thank you to Katie Mack for teaching me about this effect, and to Janelle Shane for describing redshifts as 'like galaxies sinking into a pool of dilute blood,' which is how I'll see them from now on.

Explanation

This comic references multiple physics and maths concepts, including Angular diameter, Angular diameter distance, Redshift, and mobile phones, although mobile phones are not a core science at this time.[citation needed]

The comic shows the galaxies of the universe as Samsung Galaxy mobile phones, pairing the age we see them at from earth, the degree they are redshifted, and how much of the sky they take up, known as their angular diameter. The mobile phones that are closer and older have depleted batteries, whereas the batteries are full for those phones from which the light is still only beginning to reach us. This is how galaxies appear in the sky if they were phones that had batteries lasting billions of years, the light reaching us from deeper into the past as it comes from objects that are farther away. Phones at a low battery may be a reference to 1373: Screenshot, where Randall commented that it is hard to pay attention to any phone with a low battery as the need to charge it is so urgent.

An important takeaway from this comic is that the events that occurred at the very start of our universe are etched in our sky as if they are still happening now, in a detailed faint timeline, that we are still learning more and more from. Using the mobile phone metaphor helps as, when the technology space was young and smaller there were mobile phones, such as the original iPhone, which one

might still remember despite there being many more recent and better ones in a more crowded market space.

Randall's intent appears to be to highlight how just a few very distant galaxies occupy incredibly large proportions of the sky and are seen as they were at a very young age. Mobile phones have this similarity, of massive presence, relatively early stages of new technology, and bringing information from far away.

The large galaxies can be seen in dark red in the background as if the unimaginably ancient child galactic bodies are looming forebodingly behind everything else. The title text refers to galaxies falling into a pool of dilute blood. This isn't what redshift actually is [citation needed] (rather, it's an effect on the wavelength of light), but is an evocative comparison.

This physical concept has a lot of juxtaposition of things that usually contradict, and Randall has put energy into attempting to highlight that.

Katie Mack tweet: https://twitter.com/AstroKatie/status/1516548836709 343238

A spacetime diagram possibly has reasonable visualizations of the kinds of relations bodies have when they are moving this far apart, including angular diameter distance. Simultaneity no longer exists at such distances. Distance is debated too, although that would be a different article.

#2623: Goofs

May 23, 2022

GOOFS (78)

THE SPACE DETECTIVE'S OFFICE IS ON CHESTNUT AVE, BUT LOWER MANHATTAN HAS NO STREET BY THAT NAME. AGENT GLENNIFER PURSUES THE CYBERNETIC DOG ONTO WHAT IS CLEARLY LUDLOW STREET.

THE AGENTS DESTROY THE BLIMP DRONES IN UNION SQUARE WITH HARPOONS FROM A STORE DISPLAY RACK. THE NEAREST HARPOON STORE IS SEVERAL BLOCKS AWAY AND HAS NO OUTDOOR DISPLAYS.

THE APARTMENT IN THE BACKGROUND OF THE HOLOGRAM KISSING SCENE ACTUALLY EXISTS IN DOWNTOWN VANCOUVER. WE CALLED THE OWNERS, WHO CONFIRMED THEY HAD NO RESIDENTS NAMED

SOMETIMES THE IMDB "GOOFS" SECTION REALLY SEEMS TO STRUGGLE WITH THE WHOLE PREMISE OF FICTION.

The film is set in 2018, but when Commander Bremberly chases the hologram through Times Square, there's a billboard for Avengers: Age of Ultron. Depending on the date, that billboard would have been advertising either Infinity War or this movie.

Explanation

IMDb is the Internet Movie Database, a website that contains detailed, user-contributed information about movies and TV shows. One of the sections in many entries is "Goofs". This may list bloopers, inconsistencies, implausible actions, anachronisms, etc. in the movie. While some people find enjoyment in searching for these errors, to others, the entries listed can often be overly pedantic and missing the point[citation needed] (a problem that can often afflict sites that rely on users to provide their content [Hey! Who are you calling a pedant?]). The comic makes fun of this with several goofs that simply point out differences between something in the movie and reality; but since the movie is fiction (in this case, a science fiction film that includes a space detective, a cybernetic dog, blimp drones, and a hologram kissing scene), one can say that these "goofs" might simply be more differences between the movie world and our own.

In the first goof, a named street doesn't actually exist in the city in which the movie is set. Unless the address is important to the plot (Manhattan has a number of streets with well-known characters - for example, the main theatre district is on Broadway, Fifth Avenue is a major shopping district, and Wall Street is known for large financial institutions), screenwriters can and do make up street names. It might actually be expedient to 'rename' a setting in many cases, to avoid issues such as fans showing up at said street and harassing the residents.

In the second example, they point out that there's no harpoon store at the location where the characters obtain a harpoon in the movie, and the nearest actual harpoon store doesn't have a display window. Movies take liberties with details like this for plot expediency, and is not considered a goof. Manhattan does not appear to have any notable harpoon stores,[citation needed] with or without the kind of frontage described.

In the third example, the background of a scene is of an apartment in Downtown Vancouver (a cheap and popular filming location that frequently stands in for other cities). The goof points out that the real-life apartment does not belong to the character who supposedly lives in it. Fictional movie characters do not exist in reality,[citation needed] and many scenes are set in fictional locations that are completely separate from their real-life filming locations. As such, this is only a "goof" if the scene is taken entirely literally.

The title text describes an actual anachronism. The film is set in 2018, but there's a billboard for the movie Avengers: Age of Ultron, which came out in 2015, while the next Avengers film, Avengers: Infinity War, came out in 2018. Assuming the movie was filmed before 2018, the filmmakers wouldn't have known what films would be current at the time it would be released, and certainly not the artwork they'd be using to promote them. They could have chosen to set it during the time of initial filming, but again, unless the specific date is significant to the plot, it's common to set (or rather, assume) a film takes place about the same time it's released. Generic

advertisements for fictional (or parody) films might be put over egregiously obvious existing material, physically or in post-production editing, as might references to major brands – perhaps replaced by those agreed with from product placement partners.

The title text also mentions the possibility of a self-reference – the billboard could be for this film itself since it's being released at the same time it's set. This assertion that in-universe self-reference is plausible for a movie production is likely another example of the goof's writer failing to understand the basic "premise of fiction". Most movies do not exist within the fictional world they portray,[citation needed] and many audiences would find self-reference to be a far greater obstacle to suspending disbelief than an ad for the wrong Avengers movie.

#2624: Voyager Wires

May 25, 2022
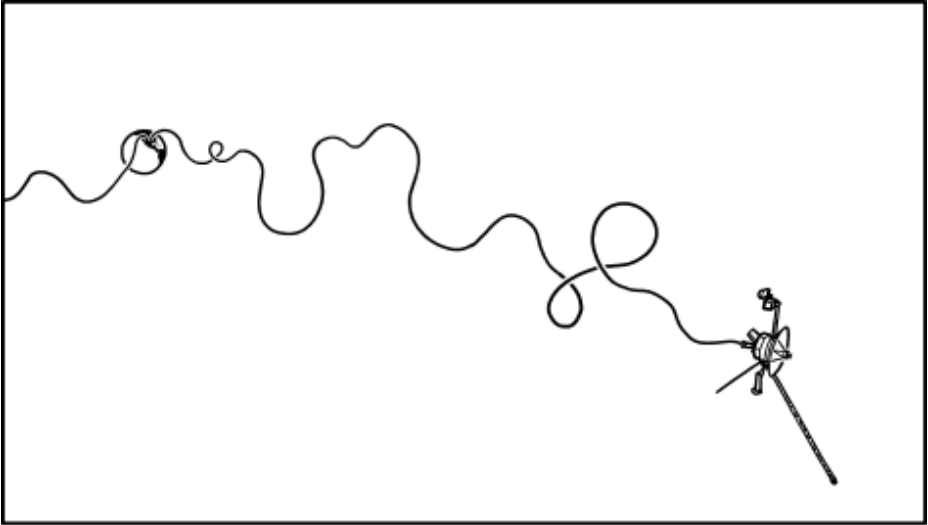
SAD NEWS: DUE TO HIGH COPPER PRICES AND BUDGET CONSTRAINTS, NASA MAY FINALLY HAVE TO CUT THE WIRES THAT THEY'VE BEEN SPOOLING OUT TO COMMUNICATE WITH VOYAGER 1 AND 2.

Also, they're getting increasingly worried that someone will accidentally hit the 'retract' button, and that the end of the cable thrashing around as it winds up could devastate the Earth's surface.

Explanation

This comic claims that the Voyager probes communicate with NASA though ridiculously long copper wires. These wires would have to be continuously lengthened as the probes travel away from Earth. Supposedly, because of "high copper prices and budget constraints," they may not be able to afford to lengthen the wires much longer. If this occurred, they would have to either cut the wires or let them break, which would prevent any further communication with the probes. In reality they use radio waves, not long copper wires, so this doesn't actually happen.

If copper wires were dragged by the Voyager probes, assuming a 1 mm² thick cable, 550 tons of copper would be needed per hour and it would add 1 million ohm per hour to the cable resistance. At $8,720/ton, this would cost just over $42 billion dollars/year, which would be nearly twice NASA's entire annual budget.

The resulting wire would slow down the probes by drag unless the wire itself was actively suspended (i.e. accelerated) continuously as it was fed. The wire could not be used for any other mechanical purpose such as a space elevator for this reason.

Since the Earth spins, the wires would also spool around the Earth, slowing the probes down even further. Clearly, this is not a good idea. This problem might be avoided if the wires reached Earth at one of the poles. Or

perhaps they could go to an airplane that flies around Earth at exactly 15 degrees of longitude per hour, with periodic air-to-air refueling, so that it is always on the side of the Earth facing the probe.

Because the Voyager probes aren't in the plane of the Earth's orbit around the Sun, the Earth would not, in its rotation around the Sun, drag these copper wires through the Sun. If it did, the wires would melt, as copper melts at around 1360 K, while the Sun's surface is approximately 5700 K.

The title text references the phenomenon seen with self-retracting cables, such as are commonly found on vacuum cleaners, where the free end of the cable, where the plug is, oscillates more and more wildly as the cable approaches full retraction, leading to the danger of a painful rap on the hand if it is not withdrawn in time. A planet-sized impact of this kind could cause severe damage.[citation needed]

A few days before this comic was released, NASA had reported receiving corrupted data from the Voyager 1 probe. The fact that they are receiving any data at all means that the attitude control system must be working (or else the antenna would not point at Earth), but they continue to investigate how that data could be corrupted after that point.

The consequence of a cable between a craft in space and a planetary location being suddenly retracted was recently imagined in the first episode of the Apple TV+

series Foundation, wherein a space elevator tether was severed. It didn't end well for anyone other than the terrorists, who won the freedom of thousands of inhabited worlds which had formerly suffered under the jackbooted oppression of Trantor's fascist galactic Empire regime. Another illustration in fiction of a severed space elevator is in Red Mars, part of the Mars Trilogy by Kim Stanley Robinson.

Black Hat has previously severed a space elevator tether using a pair of scissors in an earlier comic.

#2625: Field Topology

May 27, 2022
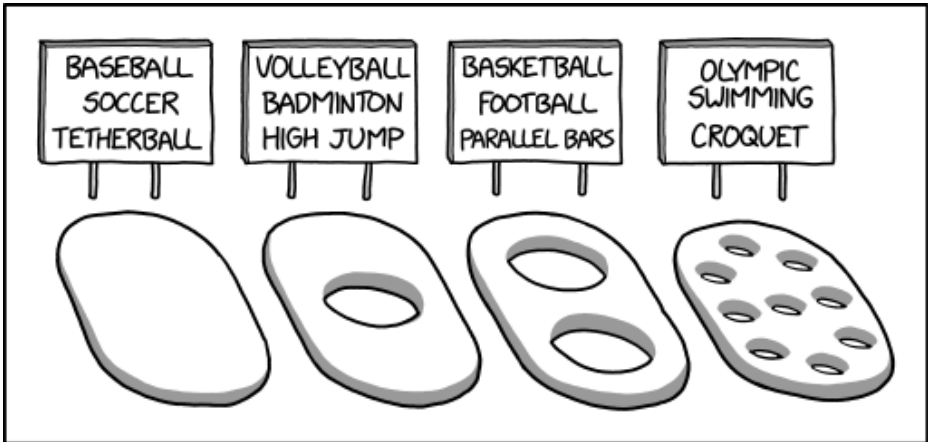
NO ONE EVER WANTS TO USE THE
TOPOLOGY DEPARTMENT'S ATHLETIC FIELDS.

The combination croquet set/10-lane pool can also be used for some varieties of foosball and Skee-Ball.

Explanation

Field Topology is a subject in mathematics, but in this comic, Randall is instead examining the topology of playing fields used for various sports. The comic strip depicts a situation in which the common practice of multi-use athletic facilities has been organized by the "topology department" and constructed to be shared by all sports whose normal playing fields are topologically equivalent. One key assumption in topology is that you can ignore the specificities of shape, size and material of the objects concerned. This presents an amusing contrast as the "equivalent" topology department playing fields are actually not very appropriate for the activities listed in the comic, as the standard positioning, size and shape of hoops, nets and bars and the material of the field itself are not equivalent to the real playing fields used for those activities.

(Not to be confused with mathematical fields, or the Fields Medal prize -- although the concept is likely a further pun in the comic, as math (including topology), and most things once can imagine really, are mostly performed ("played") within mathematical fields.)

In topology, shapes which can be smoothly deformed into one another without adding or removing holes are considered equivalent. A topological hole is an area of the nominal space (or area, or other manifold) through which nothing restricted to this topology can pass. A loop is a path across the allowable territory of a topology

(or a viable circuit to make through the world it describes) that end up where it started. For example, when describing the space taken up by a solid object such as a coffee mug, the handle forms a loop with a hole through it. If a loop cannot be tightened (ultimately adjusted to take a shorter path) down to a single point, then it must be wrapped around at least one "topological hole", and you have separately unique paths (or points, i.e., on different disconnected topologies) where you cannot adjust one loop to take the route of another without severing a looped path and reconnecting it.

When describing a negative space, such as the space around an archway, the 'hole' would be the material of the arch itself. This is because a loop formed by a ring around any part of the arch material can only be shortened to a finite length, not to a point; the 'hole' is the arch-shaped obstruction which forces the existence of these loops. A basketball hoop connected to the ground forms a similar obstruction with a loop through it, so the space around the hoop contains an equivalent hole. In this comic the topology department has analysed the spaces where various sports are played by the number of such obstructions in the playing area. Each space depicted in the comic is then signposted with the sports which are played on a field with that number of holes.

Baseball, tetherball and soccer are played on fields which are continuous in three-dimensional space. This means it is possible to traverse any path around or over any of the structures defining the field, while there are no obstructions which can be traversed through in a loop

around them. The goals on a soccer field presumably do not create holes because the goalposts and crossbar are connected to the field by the net; Randall apparently considers these to form continuous surfaces which do not allow loops through them.

Volleyball and badminton are played using a net suspended from poles, and the high jump has a bar that contestants jump over. The structure formed by the net or bar and the supporting poles can be considered to be a "hole" through the playing field, as a path over and under the net/bar forming a loop cannot be contracted to a single point, so their playing fields in the comic all have one "hole".

A basketball court has two hoops. Parallel bars can be thought of as two archways. Both have opportunities to pass through either (or both) structures, and so the material of the structures define a hole in the topological abstract of the playing 'space'. Since we are told that these sports fields belong to the Topology Department - and are not necessarily generalized to all sports fields - we might assume that their "football" field is either for rugby or for American football using H-shaped uprights.

An Olympic-sized swimming pool has ten lanes, and thus nine lane dividers which are fastened to the walls of the pool at each end, creating topological holes through the play area. Each hoop in croquet is similarly a hole through the space; while most versions of croquet use six hoops, nine hoops are used for "backyard croquet" which is played recreationally in the United States and Canada.

The fact that the space in a swimming pool is typically filled with water[citation needed] has been overlooked by the topology department.

As mentioned in the title text, this last configuration is also homeomorphic to a foosball table (with each rod sustaining the player figures above the table defining a hole) or a Skee-Ball lane (which is even more straightforward, as it is just a plane with several holes in which to throw balls). These "fields" don't actually have the same number of holes, but are apparently lumped together by the Topology Department as having "many" holes.

Unfortunately, the Topology Department does not seem to have a field for hurdling events.
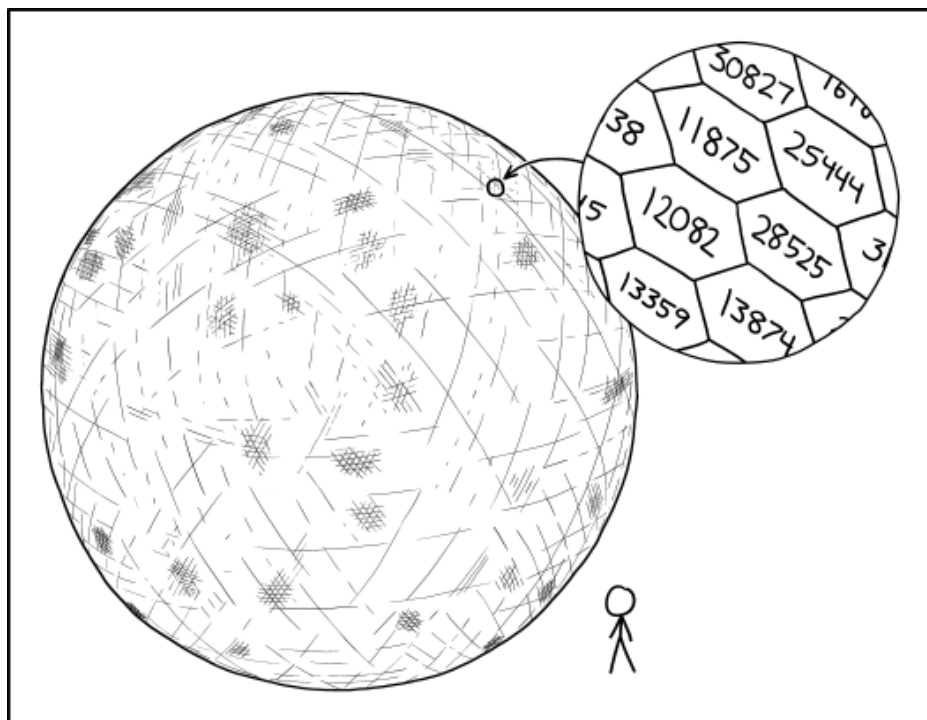
THE HARDEST PART OF SECURELY GENERATING
RANDOM 16-BIT NUMBERS IS ROLLING THE d65536.

They're robust against quantum attacks because it's
hard to make a quantum system that large.

Explanation

In binary computing, 16 bit unsigned numbers range from 0 to 65535, for a total of 65536 unique numbers, a number which is hence well-known to software engineers. Generating large numbers in a manner that is truly random is a recurring problem in cryptography, required to send private messages to another party. People today still use dierolls to generate private random numbers.

In role-playing games (and occasionally in other tabletop games), multiple shapes of dice are often used to generate random numbers in specific ranges. By convention, these are referred to as dn according to their number of faces. A traditional six-faced die would be a d6, and many popular pen-and-paper role-playing games use dice ranging between d4 and d20. While there are larger dice used in tabletop games (most commonly d100), these are usually split into multiple smaller ones. For example, a d100 is often two d10s rolled together, with one die providing the first digit and the other die giving the second digit — the total number of possible combinations (100) is the product of the number of faces of the two dice (10 * 10). While "real" d100s and other large-numbered dice do exist, most people consider them to be impractical: they need to be either impractically large or have very small faces (resulting in small print for the numbers), they're close enough to being spheres that it's difficult to get them into a stable resting position, and even if they are stationary, determining which face is "on

top" is difficult to do by eye. The Zocchihedron (d100) die is also difficult to ensure as unbiased because of geometry requiring dissimilar faces and therefore a different mixture of 'stopping factors' for each face it could land upon. The largest unbiased die is a d120 (excluding the bipyramids and trapezohedra, which can theoretically be made with arbitrarily many sides), so it is very likely that Cueball's d65536 die is also biased.

Here, Cueball has constructed a d65536 for generating random 16 bit numbers. It may have solved the problem of generating large random numbers with fewer die rolls, but it magnifies all of the problems with large-numbered dice to ludicrous extremes. In order for the faces to be readable, the die is ridiculously huge, dwarfing the human standing next to it. Rolling such a die is not only physically challenging, but it would also need a huge space in which to roll if the result is to be random, and that space would need to have an extremely flat and rigid surface in order for the die to come to rest. And even if those problems were solved, simply getting to a vantage point to see the top of the die would be a major challenge, and determining which number was truly on top would be near impossible to do by eye. If one really wished to use dice, it would be much easier to simply use multiple dice rolls. For instance, one could roll eight d4 dice (or use 16 coin flips), and convert the result into binary. This has the same randomness as a single die roll,[citation needed] but can take much longer, so people do purchase d16s to simplify it and speed it up.

The closest regular shape similar to the depicted in the

comic could be a Goldberg polyhedron. However, no such polyhedron exists with exactly 65536 hexagonal faces. The closest Goldberg Polyhedron has a mixture of 65520 hexagons and 12 pentagons, totaling 65532 faces. It is possible to construct a fair die without a matching regular shape by limiting the sides which it could land on and designing those sides to be fair (for instance, a prism with rectangular facets that extend its entire length, and rounded ends to ensure it doesn't balance on end).

The title text references how cryptographic systems (especially RSA and other factoring-is-hard based systems) are vulnerable to quantum attacks as quantum computing technology develops. The title text is essentially punning on the idea of a "large" quantum system. "Large" in the quantum computing sense would be on the order of 64 qubits, each of which would be an atom or two at most. This would still be microscopic and will never be as large as the giant die the comic is centered on; but for a well-observed environment and human rolling without sufficient entropy (consider somebody obsessed with a certain number dropping the die on something soft), a conventional computer could predict some rolls. See also 538: Security (no, not that one) for non-mathematical paths of cryptography.

Since 65536 is 2^16, if for some reason you must simulate a D65536 using nothing but D&D dice, the most efficient method is to roll a D8 4 times and roll a D4 twice ($2^{(3×4)} \cdot 2^{(2×2)}$), or roll a D8 5 times and toss a coin ($2^{(3×5)} × 2$).

#2627: Types of Scopes

June 01, 2022

	REGULAR ____SCOPE	ELECTRON ____SCOPE	RADIO ____SCOPE
MICRO	LOOK AT SMALL STUFF	LOOK AT *REALLY* SMALL STUFF	FIGURE OUT WHY YOUR RADIO BROKE
TELE	LOOK AT STUFF THAT'S FAR AWAY	DETECT COSMIC RAYS	LOOK AT DISTANT HIGH-ENERGY STUFF
PERI	LOOK FOR ENEMY SHIPS	EXAMINE THE HULL OF AN ENEMY SHIP FOR STRUCTURAL FLAWS	LET THE CREW OF YOUR SUBMARINE LISTEN TO NPR
STETHO	LISTEN TO A PATIENT'S CHEST	BURN A PATIENT'S SKIN	PLAY THE NOISES FROM A PATIENT'S CHEST ON NPR
KALEIDO	SEE COOL SHAPES AND COLORS	SEE COOL BREMSSTRAHLUNG	ANOTHER WORD FOR THE "SCAN" BUTTON
GYRO	BALANCE BY SPINNING	ANOTHER WORD FOR ELECTROMAGNET	ANOTHER WORD FOR TURNTABLE
HORO	GET RANDOM LIFE ADVICE	PREDICT A PARTICLE'S QUANTUM STATE	GET RANDOM LIFE ADVICE FROM EXPLODING GALAXIES

An x-ray gyroscope is used to determine exactly which toppings they included in the pita.

Explanation

Electron microscopes, electron telescopes and radio telescopes are special forms of microscopes and telescopes, respectively. This comic explores what you could do with a hypothetical "electron ___-scope" and "radio ___-scope" for other "regular" items whose name also ends in -scope (namely: periscope, stethoscope, kaleidoscope, gyroscope and horoscope).

The third column with "radio" often plays on different meanings of the word radio: 1) related to radiation and 2) a device for receiving radio communication or broadcasts.

The title text makes a pun on "gyroscope" and a middle-eastern pita wrap called a "gyros", incorrectly taken to be plural by many non-Greek speakers.

Table with scopes[edit]

#2628: Motion Blur

June 03, 2022

EXPERT PHOTOGRAPHERS CAN LEARN TO GENERATE THEIR OWN MOTION BLUR TO COMPENSATE FOR OTHER PEOPLE'S BAD CAMERA SETTINGS.

I can't speak for your other subjects, but MY motion was as smooth and natural as the framerate allowed.

Explanation

White Hat is recording a video while rotating (panning) the camera. Cueball notices that the camera's shutter speed is too fast, which could cause the result to look unnatural or like a sequence of still images instead of like smooth motion when turning the camera. Cueball decides to solve this problem by making himself blurrier than normal, counteracting the problems of the high shutter speed.

This is analogous to something much more common that people do, by practicing moving their bodies relative to the motion of the camera: reducing blur when the shutter speed is too low.

The title text refers to the fact that only one object - in this case, Cueball - appearing blurry while everything else in the frame is sharp is even more exotic. It can also be seen as a celebration and sarcasm regarding the rare experience of valuing having exotic knowledge and skills. It seems likely Randall has practiced reducing blur, but not succeeded at increasing it, and was possibly exposed to somebody saying "high" shutter speed when they meant "low" shutter speed, but this is presently unverified.

This is somewhat similar to a trick 'used' by some fictional characters who have the power to make themselves unclear to observers or cameras alike. In real-life it is the difference between "stop motion" and

"go motion" tricks.

When light hits a human's retina, it is perceived for a short while even after the light has ceased. This means that objects moving across a human's field of vision at a sufficient speed will naturally appear blurry – in our perception, the light arriving right now from the trailing part of the object will mix with the light that arrived a moment earlier, from the leading part of the object.

A camera's shutter speed is the amount of time that the shutter is open for each frame, allowing the image sensor to capture light. If the shutter speed is too high (relative to the frame-rate), this blurring will not occur, and the motion will look unnaturally crisp – if something is too small and/or too quick, the illusion of motion may disappear altogether; the object instead will appear as a brief flash of multiple objects standing still, like in the case of a fast-moving mouse cursor on a screen. See for instance this Videography - Slow Shutter Speed vs. Fast Shutter Speed Comparison.

In cinema, the shutter speed is generally set to double the frame-rate, e.g. 1/48 s for footage shot at 24 fps (one of the lowest standard frame-rates, a remnant from the age of mechanical motion picture cameras and film projectors).

An opposing problem is that of a camera not sufficiently matching the relative motion of a moving object, with a shutter speed that is too slow (and may need to be, given the choice of aperture and lighting conditions). Sports

photographers must learn how to scan-and-pan their subjects (runners, horses, vehicles, etc) with enough synchronicity to capture them sharply, and possibly seemingly hanging frozen in mid-air against an artistically-blurred background.

It is unclear how Cueball makes the motion blur include both his feet, as the friction with the ground should hinder them from vibrating horizontally in the manner that may cause for motion blur. Additionally, creating the kind of motion blur he does (with evenly distributed horizontal blur) requires extreme acceleration at both ends of the movement.

#2629: Or Whatever

June 06, 2022

YOU KNOW, BACK IN THE 90s, THE SEARS TOWER WAS THE WORLD'S TALLEST TOWER.

YEAH! OR "BUILDING." THE CN TOWER AND THE KVLY-TV ANTENNA WERE TALLER, BUT THE CN TOWER ISN'T ALWAYS CONSIDERED A BUILDING AND THE ANTENNA IS SUPPORTED BY GUY WIRES OR WHATEVER.
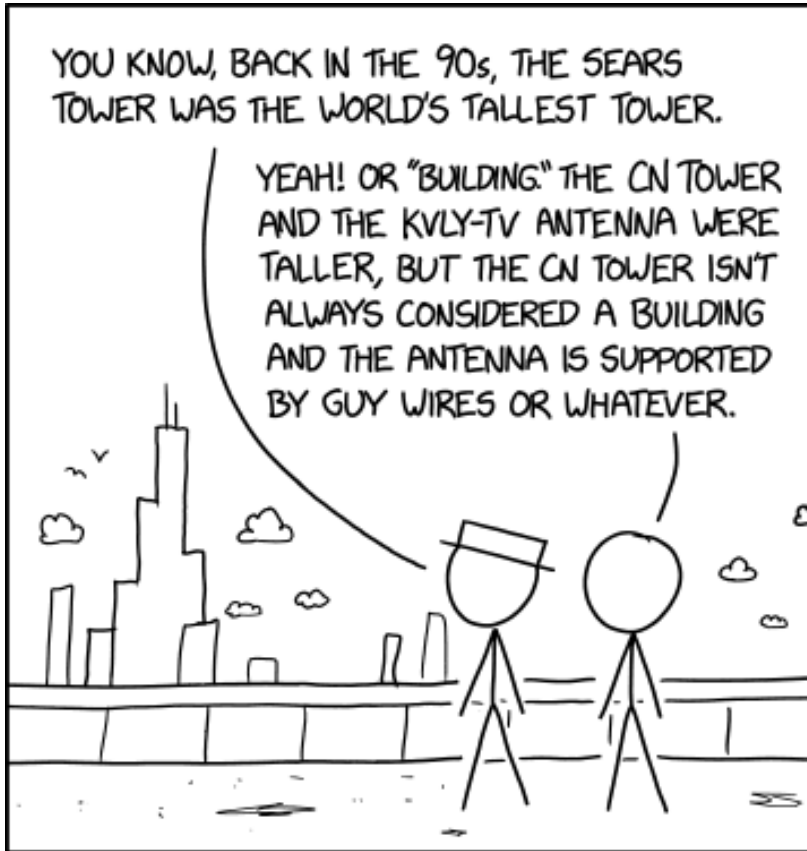
WHENEVER I GET SELF-CONSCIOUS ABOUT HOW OBSESSIVE I SOUND ABOUT SOME RANDOM TOPIC, I PANIC AND TACK ON "OR WHATEVER."

Oh yeah, I didn't even know they renamed it the Willis Tower in 2009, because I know a normal amount about skyscrapers.

Explanation

The Willis Tower (formerly the Sears Tower) is a 108-story, 442.1 meter skyscraper in Chicago. It is currently the third tallest building in North America, and was indeed the tallest building in the world for 25 years, surpassing the World Trade Center upon opening in 1973, and being surpassed by the Petronas Towers upon their opening in 1998.

White Hat conveys some interesting historical trivia to Cueball, regarding the Sears Tower. Cueball then sets the record straight by correcting White Hat's use of the word tower: In the category of 'tower', the Willis Tower was never the tallest. Cueball then realizes he just one-upped White Hat with what he knows about tall structures in general, which might make him sound obsessive, so he tags on the meaningless caveat of "or whatever".

This is meant to diffuse the tension he may have added by his well-meaning contradiction, but could also be taken as a passive-aggressive behavior by interlocutors who may already be touchy about the original 'correction'.

In the title text, being already self-conscious that he has overstepped the mark for polite small talk, he then hypercorrects the self-perceived tone of his response by explicitly denying that he knows far more about the tower, but only by providing the very facts that he is trying to claim not to know. Alternately, this could be

White Hat responding to something else Cueball said, as an annoyed way to either get Cueball to stop, or to make a point that Cueball knows more than is "normal" about skyscrapers.

This comic hinges on the debate about the tallest structure vs tallest building. A building is generally defined as a human-built structure fit for human habitation when it is fit for human habitation, while a structure is generally defined as anything humans make. (Or in some cases, anything an animal makes, like crab shells.)

It is far from unusual for the tallest building (habitable) to be shorter than the tallest structure (uninhabitable), such as in 1974 when the tallest structure was the Warsaw radio mast at 646.38 meters. The radio mast was uninhabitable,[citation needed] so the tallest building was the Sears Tower at 442.1 meters. The Warsaw tower collapsed in 1991, so it was not the tallest structure for the majority of the '90s.

After the Warsaw Tower's demise, the KVLY-TV mast, which stood at 629 meters, held the record of tallest structure until either 2000 or 2010, with the opening of the Petronius platform and Burj Khalifa respectively. (The date depends on whether you count underwater towers, as the Petronius platform is an oil rig and only 75 meters of the platform are above water.) It was also the tallest guyed mast up until 2019, when it was reduced to 605.6 meters, giving the KRDK-TV mast the record.

The CN tower stands at 553.3 meters (measured from top of spire), which is higher than the Sears/Willis tower but shorter than the KVLT-TV mast. It is mentioned as it has some habitable space but not much, causing debate about whether it is a building (referenced below). It was never the tallest structure, but if it's a building it would have been the tallest in the world from its opening in 1976 until the Canton Tower's in 2009. It is currently the 9th tallest building.

The debate surrounding the tallest building does not stop at building vs. structure. Architects have long argued about what the height definition of a building should be. Should it include antennas sitting at the top of the building? How about spires that form part of the architectural design of the building but are not part of the habitable space? Should we focus instead on the highest habitable floor? The debate has historically had relevance every time a new record is claimed by developers eager to reach new heights using any means possible (Size Does Matter, At Least In The Tallest Building Debate).

There is yet more debate about what counts as a building vs. a structure. While some people would say that any structure with any habitable space is a building, most people in the field agree that there is a certain threshold of habitable space, below which there is not enough habitable space to count as a "building", even if there is some.

A main point in this debate are TV towers, which are

often tall towers with little habitable space in them, but with an observation deck at the top. Examples include the Tokyo Skytree, Fernsehturm Stuttgart, and CN tower. A similar structure is the Dubai Creek Tower, a tower under construction in Dubai, set to become the world's tallest structure. (The Dubai Creek Tower will not, however, broadcast tv signals.)

TV towers are sometimes counted as buildings as they do have some habitable space. However, they are often not as they are commonly considered to not have enough habitable space to be buildings, hence Cueball's line "The CN tower isn't always considered a building".

Wikipedia lists the tallest structures, and this YouTube video explains a bit more about tall buildings/structures. Since 2010 the Burj Khalifa has been both the tallest structure and the tallest building in the world.

#2630: Shuttle Skeleton

June 08, 2022
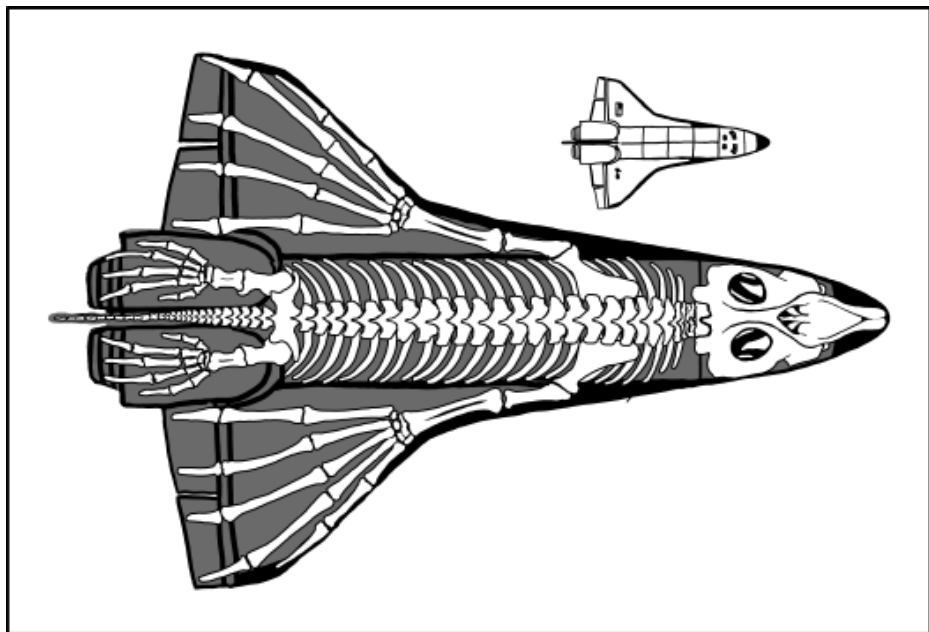
THE SPACE SHUTTLE WAS LONG ASSUMED TO BE A TYPE OF FISH OR SHARK, BUT AFTER IT WAS DECOMMISSIONED IN 2011, ANALYSIS OF ITS SKELETON DETERMINED THAT IT WAS ACTUALLY A MAMMAL.

It's believed to be related to the Stellar Sea Cow.

Explanation

The Space Shuttle was a reusable spacecraft system used by NASA from 1981 to 2011, after which it was decommissioned. In this comic, Randall suggests that the nature of the shuttle was in doubt or misunderstood until either an intact 'specimen' (of which there are four) had been dissected, or possibly the remains were reassembled from the two that were lost in accidents.

With its shape, shown in the small image, and the tail fin, it looks a bit like a bony fish or ray. The joke is that after the shuttle was taken out of use, its skeleton was analyzed, and as shown in the comic, was found to have a skeleton typical of a mammal, with details such as the pentadactyl quadripedal bodyform hidden beneath its aerodynamic sweep, as well as having bones (i.e., not primarily cartilage). This morphology is similar to that possessed by a whale. However, it should be noted that the skeleton has several features not found in mammals, e.g. the ribcages extending all the way to the pelvis and past the shoulder these features are more reminiscent of snakes. Of course, the skeleton of a spacecraft is not made of bones, but rather of metal and other manufactured materials.[citation needed]

As the understanding of the natural world developed, many taxonomic misconceptions were overturned, or at least the scientific terminology was tightened. For instance, it was found that dolphins and whales were mammals, not fish.[cetacean needed] Because of

convergent evolution – the tendency for distantly-related species to adapt similarly to a given environment – it is often not easy to properly classify organisms merely by observing their exterior. For example, whales and fish have very similar body shapes, as did the extinct plesiosaurs, because life as a swimming vertebrate favors the same adaptations. In lieu of genetic analysis, or even of sufficient observation of them in the wild, the main progress in understanding differences among marine animals was often in dissecting the corpses of creatures found stranded or caught in nets, or reconstructing them from skeletal remains. Together with fossil evidence, insights were developed about their origins and differences from others' origins.

The title text conflates the now-extinct Steller's sea cow, an aquatic mammal related to manatees and named after explorer/zoologist Georg Steller (also extinct), with the adjective "stellar", which means being of a star or stars, such as inter-stellar space or stellar masses. While this conflation is often done accidentally, due to the name Steller being much rarer than the adjective "stellar," in this case it is probably an intentional pun.

One might expect that the idea for this comic may have come from the recent California Appeals Court ruling that bumblebees are considered fish under a law which categorized several other invertebrates as part of a broad colloquial category of fish (as in "Fish and Game Department" designations.) However, given the short time between the ruling and the comic's release, it is likely that this was a coincidence.

The comic also prominently conflates biology with artifice, a budding and controversial concept in these times of rapid AI use and research.

#2631: Exercise Progression

June 10, 2022
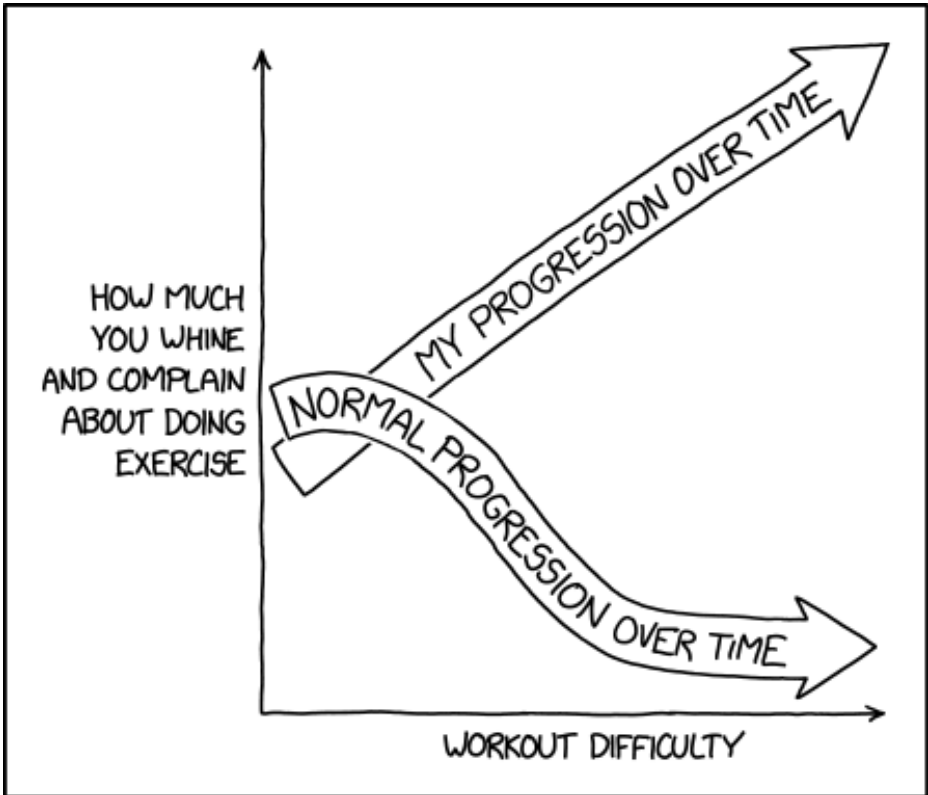
They said after I got into a routine, I'd enjoy getting progressively stronger and stop whining so much about how hard exercise was. Well, they were half right!

Explanation

The arrows on the graph progress from left to right on the axis for "workout difficulty", showing that as people exercise (both normal people, and Randall), their bodies become stronger and able handle more difficult workouts.

The "normal progression over time" arrow in the graph shows how, when normal people unaccustomed to exercise first start out, it is perceived as unpleasant, for a variety of reasons: it takes time from the day, causes them to become sweaty and hot, feels particularly difficult, causes sore muscles, and so forth. Over time, as their body becomes accustomed to the exercise and can take on higher exercise loads, increasing muscle strength and endurance, so too does the brain, increasing both the amount of dopamine in the brain, and the number of dopamine receptors, as well as other positive changes. This means the "enjoyment" rewards from exercise begin to dominate, and exercise becomes a pleasant pastime, rather than a tedious, time-consuming and perhaps painful slog. This naturally causes a related reduction in whining.

The "my progression over time" arrow shows that while his body is becoming accustomed to the exercise just like any other, Randall whines linearly with the exercise difficulty. This could be because he is not neurochemically rewarded in the same way. Randall has implied he suffers from ADD, and this is a common

symptom, caused by an excess of dopamine transporters in the brain carrying away the dopamine before it can activate the receptors.

It could also be because there are other downsides to exercising that he cares about more than the enjoyment; for example, if his exercise duration increases linearly with difficulty, and he values his time highly, that could cause a linear increase in whining with difficulty. Or since there is no scale for time on the graph, it could be that Randall has significantly misjudged the timescale of the effect (another common symptom of ADHD), and has only just begun his exercising journey: he may simply not realize that the neurological changes will take longer than the muscular ones, so he is seeing his muscles get stronger but has not yet reached the downturn in whining. Or he might just enjoy whining, and have more strength for lengthy whining sessions as his fitness increases.

Since the strip does not give information about the content of his whining, duration of exercise regimen, etc, the specific cause of the difference in whining behavior cannot be identified from the strip alone, though in the context of other strips, it is likely to be a real effect of neurodiversity.

The title text refers to the common response to such whining by people who are neurochemically rewarded by exercise, and have reached the bottom right of the graph: that getting stronger through an exercise routine will become its own reward, leading to a reduction in

whining. Randal's statement that they were "half right", together with the graph, implies that he does indeed enjoy the rightward progression on the graph as he gets stronger and is able to take on increasingly difficult exercise; but that despite their reassurances, his whining has ramped up linearly with the exercise difficulty no matter how well-accustomed to it his body becomes.

To give an idea of the scale of time on the graph, a common rule of thumb is that while gains in strength can be seen within weeks (the stretch of the graph where both arrows rise), it can take months for a neurotypical mind (and its body) to acclimate to a serious change and begin to reap the rewards[actual citation needed] (the falling area on the graph). Military boot camps are 6-13 weeks.

The strip may also be a pun, where the "normal progression" arrow traces out half of a normal curve.
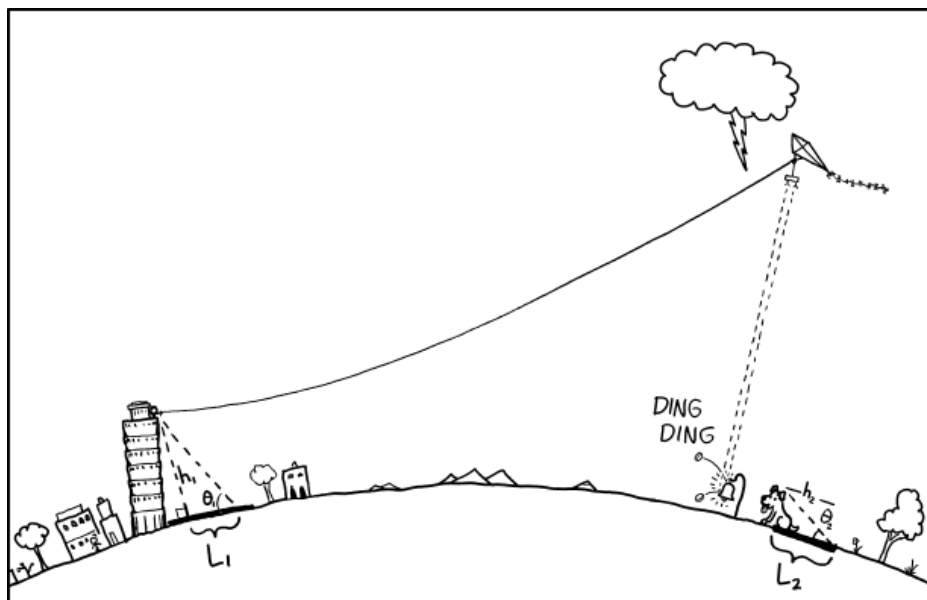
HISTORY'S GREATEST SCIENTIST WAS PROBABLY THAT ONE WHO MEASURED THE SHADOW OF THE LEANING TOWER OF PISA WHILE FLYING A KITE INTO A DISTANT THUNDERSTORM WHERE LIGHTNING CAUSED TWO MOLDY PETRI DISHES TO FALL ONTO A BELL NEXT TO A SALIVATING DOG WHOSE SHADOW ANGLE DETERMINED THE CIRCUMFERENCE OF THE EARTH.

"Ow! One of the petri dishes I left on the tower railing fell and hit me on the head! Hey, that gives me an idea…"

Explanation

This comic takes the feats of seven of history's most acclaimed scientists and combines them into one fictional act, claiming that this person was the greatest scientist in history. The joke is that pulling off a combination of all of these would be rather impressive[citation needed] from a technical standpoint, but would have little value as a scientific experiment; almost none of the things being tested are directly related to each other.

These scientists are Thales of Miletus, Galileo Galilei, Benjamin Franklin, Alexander Fleming, Ivan Pavlov, Eratosthenes, and Isaac Newton.

The ground is noticeably curved in this comic, because the curvature of the Earth is mentioned and measured.

Humorously combining multiple science experiments into one was also a punchline in 1584: Moments of Inspiration. Curved floors to represent Earths curvature were mentioned in 2412: 1/100,000th Scale World.

#2633: Astronomer Hotline

June 15, 2022
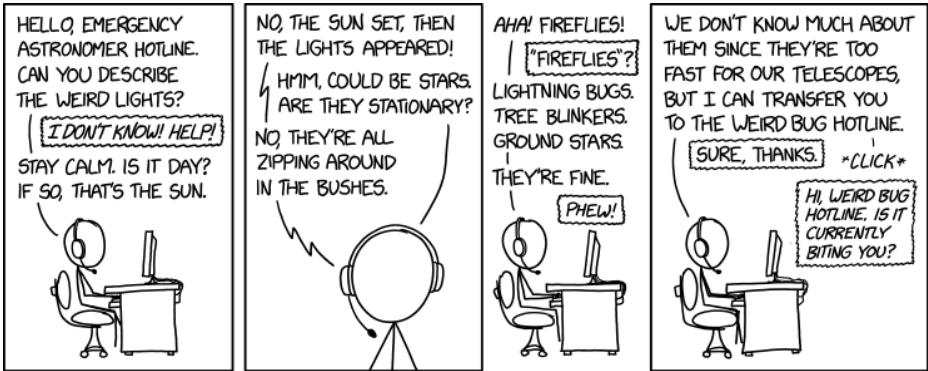
Employment statistics have to correct for the fact that the Weird Bug Hotline hires on a bunch of extra temporary staff every 17 years.

Explanation

This comic is a joke about helplines, and the experience of the skilled people staffing them, who often have to deal with callers with a much lower understanding of the subject, seeking assistance with things that may seem very basic from the point of view of the technician, or where they have completely misunderstood the nature of the issue.

The comic starts with someone having called the "Astronomer Hotline", hence the title. Judging by the way the helpline employee, Cueball, starts the call, by asking for a description of the weird lights, it is implied that this is the main/only purpose of the helpline, or is, in practice, the subject of most of the calls they receive.

The caller is in panic, and doesn't know how to describe the light. Cueball is used to this and asks the caller to stay calm, then starts to go through his checklist, asking them if it is daytime, because if it were, he might assume they have just noticed the Sun. Most people are familiar with the Sun[citation needed] and would not need help in identifying it, although people have also mistaken the Moon for a 'mysterious light in the sky' at times. Asking this could thus seem very condescending, but it is like when the employee at a tech support hot-line asks if the computer is turned on, or if the caller tried to restart the computer, see 806: Tech Support. It may also refer to the most immediate danger, as looking directly at the sun is a bad idea.

The caller is not affronted, but tells Cueball that the Sun has set. When asked if the lights are stationary, which stars would normally appear to be, the reply is that they are zipping around in the bushes.

At this point Cueball realizes that the caller has just seen fireflies, a family of insects commonly seen in temperate/tropical climates during the summer. He describes them for the caller as "lightning bugs" (another common epithet for these insects), "tree blinkers", or "ground stars" (unusual terms invented for this comic that seem to illustrate the Astronomer Hotline's unfamiliarity with fireflies); and says that these are not a problem, much to the caller's relief. Those last two descriptions, especially "ground stars", are reminiscent of the "fool's stars" mentioned in 2017: Stargazing 2.

However, Cueball must admit that astronomers do not know much about fireflies, since they are too fast for the astronomers' telescopes. This refers to the problem of object tracking in astronomy. Sufficient observations must be taken to reliably predict the future path of an object, and thereby to be able to reorient the observing equipment to track its progress across the sky and make further observations. While the relative velocity of fireflies would be much lower than that of most astronomical bodies, their movement across the field of view tends to appear much quicker, being unusually close to the observer. This, combined with their erratic, unpredictable paths, would make them very difficult to track through a telescope.

Since Cueball cannot help further, he transfers the caller to the "Weird Bug Hotline", in a process that is apparently somewhat routine – enough to have the correct line somehow preprogrammed into his call-handling system. This is clearly not the first 'astronomy' query that actually concerns fireflies. This is similar to the process that might happen when a helpline caller's query cannot be handled by first line support and has to be passed on to a more specialized second line operator, or where the call has been routed to the wrong specialist to start with, perhaps because the user, lacking knowledge about the issue, selected the wrong option from an automated routing system.

Before the call ends, at Cueball's end, he hears the opening question from the other hotline ("Is it currently biting you?") as the new support tech again goes directly to the most common/important query, whether there is any immediate danger to be resolved... It is possible that Cueball will actually be speaking to the Weird Bugs line initially, quickly priming the Weird Bug call-handler with the salient facts already established before fully handing over the call. This could get the original caller straight into the correct conversation if the onward line's handler is sufficiently competent and experienced in such a transfer.

Some people (often UFO enthusiasts) tend to get a little over-excited about calling every light in the sky they don't expect a UFO. This comic takes this to the extreme, where someone calls a helpline because they saw fireflies, and thought they were UFOs. While UFOs are not

mentioned by name, they are heavily implied. Technically, such a person would be correct, so long as the lights are actually unidentified, flying and caused by a physical object, but if the expectation is that it is an extraterrestrial spacecraft then the truth (if discovered and also accepted) can be disappointing to some people, rather than lead to an interesting alternative avenue of appreciation of whatever phenomenon it truly is.

The title text is a reference to bugs that have gaps of several years between emerging from their larval state. Most famous are the periodical cicadas, 13- and 17-year cicadas, that only emerge every 13 or 17 years depending on species. The 17 years in the title text thus refers to the 17-year cicadas. Every 17 years the bug hotline hires a bunch of temporary staff, either because there will be more callers due to the unexpected new bug no one has seen for 17 years, or it could be because they just like to emulate nature and thus do this every 17 years. Or alternately, the 17-year cicadas may just like to gather inside a trench coat and apply for jobs answering calls about weird bugs. The largest 17-year cicada appearance in the USA is called Brood X which last occurred in 2021 and before that 2004. There are smaller broods in other years, but the majority come out with 17 years interval, and the next is expected in 2038. The joke in the title text is that the employment statistics for the weird hotline have to correct for this fact, a reference to the decennial United States census, which involves so many people as to affect aggregate employment statistics. Periodical cicadas have been mentioned before in 2263:

Cicadas (see details about them in that comic's trivia section).

#2634: Red Line Through HTTPS

June 17, 2022
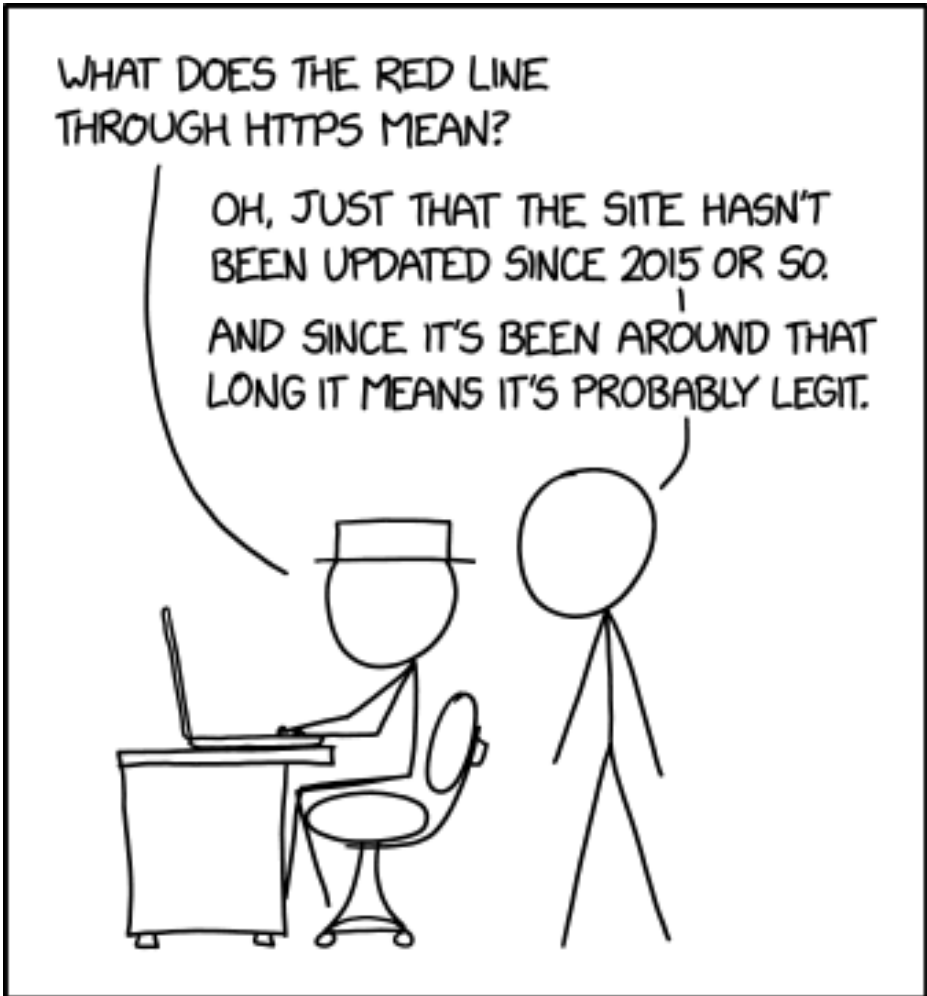
Some organization has been paying to keep this up and it hasn't been removed from search results. Seems like two votes of confidence to me.

Explanation

This comic pokes fun at the lack of security implied by an unverified https connection as implied by the "red line through (https)". https is an extension to the http protocol which (among other things) verifies that the server owns the domain name. "Insecure" https is usually caused by invalid TLS certificates, which can be an indication that an attacker is intercepting the connection (the attacker doesn't have access to the certificates). However reasons for "insecure" https are often benign:

- The certificates expired, and the site maintainers have not asked for new certificates.
- The certificates are self-signed by the owners.
- The client has an outdated list of CA certificates.

A comprehensive list of reasons associated with server misconfigurations can be found on badssl.

Although a lack of the https protocol in a web process does allow for third party tampering and deception, it also implies that the site is rather old; and, if it has been maintained for this long, it is probably not malicious, as most malicious sites are either reported and taken down or allowed to become defunct by their operators after a short amount of time.

The title text essentially explains the joke, noting that maintaining a website costs money and that there are regulatory agencies responsible for taking down sketchy

domains, and so if a website is still up despite these obstacles, it is probably trustworthy.

A similar question was asked on 1256: Questions.

#2635: Superintelligent AIs

June 20, 2022
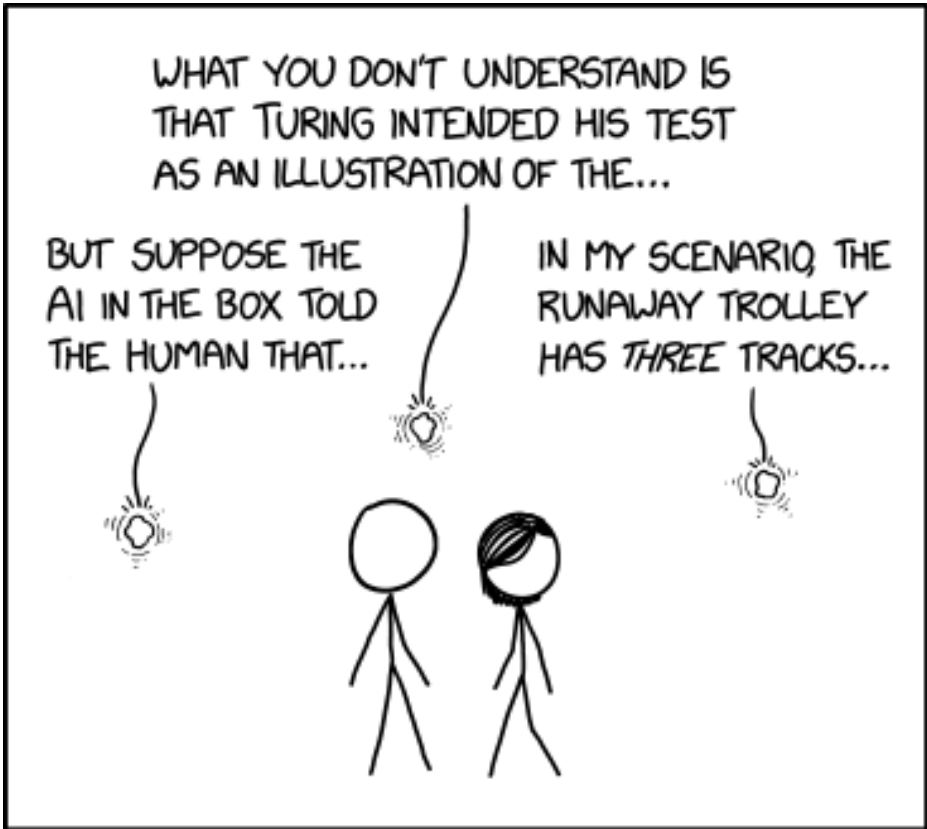
Your scientists were so preoccupied with whether or not they should, they didn't stop to think if they could.

Explanation

Artificial intelligence is a recurring theme on xkcd. Superintelligent AI, such as has been theorized to arise under a hypothetical "singularity" situation, is said to be a new kind of artificial general intelligence. Randall, however, proposes a qualification: that a superintelligent AI would likely have been programmed by human AI researchers, and therefore their characteristics would be molded by the researchers that created them. And as AI researchers tend to be interested in esoteric philosophical questions about consciousness,[citation needed] moral reasoning, and qualifications indicating sapience, there is reason to suspect that AIs created by such researchers would have similar interests.

In this comic we see Cueball and Megan surrounded by three AIs who are seemingly only interested in classic problems and thought experiments about programming and ethics. The three topics being espoused by the AIs are:

• AI box — A thought-experiment in which an AI is confined to a computer system which is fully isolated from any external networks, with no access to the world outside the computer, other than communication with its handlers. In theory, this would keep the AI under total control, but the argument is that a sufficiently intelligent AI would inevitably either convince or trick its human handlers into giving it access to external networks, allowing it to grow out of control (see 1450:

AI-Box Experiment). Part of the joke is the AIs in the comic aren't 'in boxes', they appear to be able to freely travel and interact, but one of them is still talking about the thought experiment anyway, adding to the implication that it is not thinking at all about itself but of a separate (thought?) experiment that it has itself decided to study. The AI box thought experiment is based in part on John Searle's much earlier Chinese room argument.

- Turing test — An experiment in which a human converses with either an AI or another human (presumably over text) and attempts to distinguish between the two. Various AIs have been proposed to have 'passed' the test, which has provoked controversy over whether the test is rigorous or even meaningful. The AI in the center is proposing to educate the listener(s) on its understanding of Turing's intentions, which may demonstrate a degree of intelligence and comprehension indistinguishable or superior to that of a human. See also 329: Turing Test and 2556: Turing Complete (the latter's title is mentioned in 505: A Bunch of Rocks). Turing is also mentioned in 205: Candy Button Paper, 1678: Recent Searches, 1707: xkcd Phone 4, 1833: Code Quality 3, 2453: Excel Lambda and the title text of 1223: Dwarf Fortress.

- Trolley problem — A thought-experiment intended to explore the means by which humans judge moral value of actions and consequences. The classic formulation is that a runaway trolley is about to hit five people on a track. The only way to save them is to divert the trolley

onto another track, where it will hit one person. The subject is asked whether they would consider it morally right to divert the trolley. There are many variants on this problem, adjusting the circumstances, the number and nature of the people at risk, the responsibility of the subject, etc., in order to fully explore why you would make the decision that you make. This problem is frequently discussed in connection with AI, both to investigate their capacity for moral reasoning, and for practical reasons (for example, if an autonomous car had to choose between, on the one hand, having an occupant-threatening collision or, on the other, putting pedestrians into harms' way). The AI on the right is not just trying to answer the question, but to develop a new variant (one with three tracks, apparently), presumably to test others with. This problem is mentioned in 1455: Trolley Problem, 1938: Meltdown and Spectre and in 1925: Self-Driving Car Milestones. It is also referenced in 2175: Flag Interpretation and 2348: Boat Puzzle, but not directly mentioned.

The title text is a reference to the movie Jurassic Park (a childhood favorite of Randall's). In the movie the character Dr. Ian Malcolm, a mathematician focused on chaos theory and played by Jeff Goldblum, criticizes the creation of modern dinosaurs as science run amok, without sufficient concern for ethics or consequences. He states that the scientists were so obsessed with whether or not they could accomplish their goals, that they didn't stop to ask if they should. Randall inverts the quote, suggesting that the AI programmers have invested too much time arguing over the ethics of creating AI

rather than trying to actually accomplish it.

This comic was likely inspired by the recent claim by Google engineer Blake Lemoine that Google's Language Model for Dialogue Applications (LaMDA) is sentient. This assertion was supported by a dialog between Lemoine and his colleagues, and LaMDA which includes this excerpt:

The AIs in this comic are depicted as floating energy beings, like LaMDA mentions. This is similar to the 1450: AI-Box Experiment, although those in this comic look somewhat different. This raises the question of whether LaMDA's training data might include xkcd or explain xkcd, and has obtained the description of such a self-image from the earlier comic or (more likely, since LaMDA is trained on text instead of images) commentary on it from here on this website.

While LaMDA is not the first very large language model based on seq2seq technology which has been claimed to be sentient, it does have a variety of new characteristics beyond what those of its predecessors, such as GPT-3 (including OpenAI's Davinci) and NVIDIA GPT-2 offshoots, include. In particular, LaMDA's deep learning connectionist neural net has access to multiple symbolist text processing systems, including a database (which apparently includes a real-time clock and calendar), a mathematical calculator, and a natural language translation system, giving it superior accuracy in tasks supported by those systems, and making it among the first dual process chatbots. LaMDA also is not stateless,

because its "sensibleness" metric (including whether responses contradict anything said earlier) is fine-tuned by "pre-conditioning" each dialog turn by prepending 14-30[citation needed] of the most recent dialog interactions, on a user-by-user basis.[p. 6 here] LaMDA is tuned on nine unique performance metrics, almost all of which its predecessors were not: Sensibleness, Specificity, Interestingness, Safety, Groundedness, Informativeness, Citation accuracy, Helpfulness, and Role consistency.[ibid., pp. 5-6.]

#2636: What If? 2 Countdown

June 22, 2022

If you don't end the **99 Bottles of Beer** recursion at N=0 it just becomes **The Other Song That Never Ends.**

Explanation

This comic takes the idea of advent calendars to the extreme. It uses absurd and obscure ways to measure the amount of time until Randall's new book What if? 2 is released, with esoteric units and esoteric numbers. See explanation of each day in the table below. Some concepts that appear multiple times throughout the calendar are:

- SI prefixes, which can be applied to the beginning of a unit's name to multiply or divide the unit by powers of 10 or 1,000. This is standard for units like meters and grams, but is rarely applied to measurements of time other than when a unit of less than one second is needed, most commonly in various fields of science and engineering such as physics and electronics.

- The Gettysburg Address, a famous speech delivered by U.S. president Abraham Lincoln in 1863, where he began by referring to the signing of the Declaration of Independence taking place "four score and seven years ago". A score is a dated term for the number 20, so "four score and seven" is equivalent to 87.

- A dog year is traditionally considered to be one-seventh the length of a normal human year, since a dog's overall lifespan is roughly one-seventh of a typical human's. The comic applies this to other units of time, such as minutes and months, each of which is also one-seventh the length of the standard unit. The number seven (traditionally a "lucky number") is also used in many of

the numbers quoted in the calendar.

- Other comparative durations of time that are not normally or usefully applied to day-length multiples. At the top end, there is the age of the universe, at the other there is Planck-time – with entire durations of periods of human history and the time needed to watch popular TV/film franchises in-between – most of which require a non-trivial multiplier or divisor to bring them to the necessary scale required.

- A baker's dozen is 13, or one more than a normal dozen. Here, the "baker's" prefix can be applied to any unit by adding an extra one of its constituent parts, like an extra hour added to a day.

- Irrational numbers like pi (3.14159...), Euler's number or e (2.71828...), the golden ratio (1.61803...), and the square root of 2 (1.41421...). These are all interesting numbers because of their mathematical properties, but very impractical to use as arbitrary measurements of time because they have an endless series of non-repeating decimal digits.

- The teenage dating game Seven minutes in heaven.

- Rotational and orbital periods of various bodies in the Solar System.

- The song 99 Bottles of Beer is also used twice in the calendar, as the one after a full week and then for the final day before release.

The title text refers to the recursive time period on the final day before release, September 12, where the 99 Bottles of Beer song is sung 99 times, but with one less

verse every time (so 99 verses the first time, 98 verses the second, 97, 96 ... 2 and 1 the last). If you don't stop when you reach N=0 bottles, the repetition never ends, so that time interval becomes infinite. He then calls it "The Other Song That Never Ends", comparing it to The Song That Never Ends. That song is a repetitive children's song, which is specifically intended to go on forever. The difference is that the Beer song has a natural stopping point at 0, while The Song That Never Ends is completely repetitive.

Table of the calendar countdown[edit]

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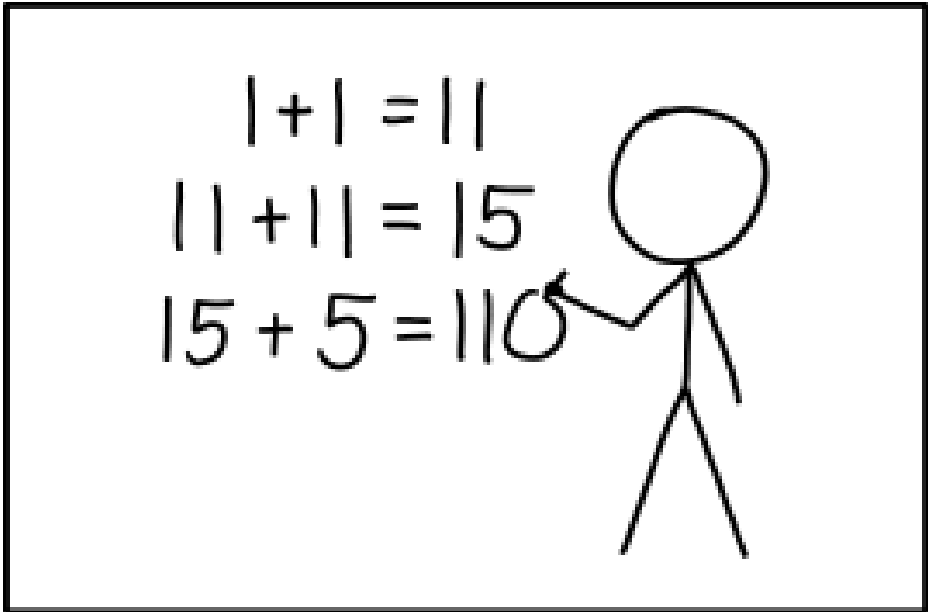
REMEMBER, ROMAN NUMERALS ARE ARCHAIC, SO ALWAYS REPLACE THEM WITH MODERN ONES WHEN DOING MATH.

100hel00k out thls lnno5at4e strlng enl00o50lng l5e been 500e5e50oplng! It's 6rtual00y perfel00t! ...hang on, what's a "virtuacy"?

Explanation

Roman numerals are the system of representing numbers used during the Roman Empire. The letters I, V, X, L, C, D, and M are used to represent numbers, with each letter representing a consistent value. Specifically, I represents 1, V represents 5, X represents 10, L represents 50, C represents 100, D represents 500, and M represents 1000. One way of stating the rules for combining Roman numerals next to each other are that a Roman numeral is added to a Roman numeral of equal or lesser value just to its right (e.g., II=1+1=2 because 1≥1, and VI=5+1=6 because 5≥1[citation needed]), and a Roman number is subtracted from a Roman numeral of greater value just to its right (e.g., IV=5-1=4 because 1<5, and IX=10-1=9 because 1<10). (Also, each place must be written separately, e.g., one cannot represent 49 via IL but instead must represent the tens place and ones place separately via XL IX—although the space would not be included in practice).

The modern system of representing numbers is a decimal positional notation using the numerals (0, 1, 2, 3, 4, 5, 6, 7, 8, and 9). Westerners often call this system "Arabic numerals" or "Hindu–Arabic numerals" because they were invented in India and introduced to Europe by Arabic merchants.

Thus in Roman numerals a digit always has the same absolute value but may be treated as positive or negative depending on the digit after it, whereas for

Hindu-Arabic numerals, a digit's value changes by a power of 10 depending on its absolute position and is never subtracted.

Cueball's original equations in Roman Numeral form are:

Translated normally into more familiar Hindu–Arabic numerals, these equations are:

But Randall/Cueball replaced each letter individually with its value in Hindu-Arabic numerals — ignoring the abovementioned rules for interpreting combined Roman numbers, instead using the rules of Roman Numerals. "I" is replaced with "1", "V" is replaced with "5", and "X" is replaced with "10". For example, for IX at the end of the last equation, "I" is replaced with "1", and "X" is replaced with "10", so "IX" becomes "110". Thus, the equations are written

where the spaces have been added for clarity.

An alternative interpretation of the third line, though not strictly in accordance with Roman numeral "rules", is

The joke is that because Arabic numerals do not use the same rules of addition and subtraction as Roman numerals, the equations appear incorrect in both systems. The usual interpetation of 11 is 10+1, not 1+1 as it is under the rules for interpreting Roman numerals. Randall derives additional humor from the premise that Cueball seems to know Roman numerals better than Arabic numerals (as demonstrated by the fact that he

translated only the symbology and not the grammar) so that he would do math in Roman numerals and have to remember to convert his equations to Arabic numerals at the end. Schoolchildren in the West have been taught to do math with Arabic numerals, not Roman numerals, for centuries.

In the title text, Randall applies the same idea of replacing Roman numerals with their values in Arabic numerals to strings of English words.

The original string (with letters that would be interpreted as Roman numerals capitalized) is, "CheCk out thIs InnoVatIVe strIng enCoDIng I'Ve been DeVeLopIng! It's VIrtuaLLy perfeCt!" For the first word, "Check," C is replaced with the value of that Roman numeral in Arabic numerals, i.e., "100", in both instances within the word, which results in "100he100k". Unlike in the comic, Randall combines Roman numbers using the proper rules of addition and subtraction. For example, he replaces "IV" with "4", not "15", e.g., "innovative" becomes "1nno5at4e", not "1nno5at15e". (However, "I've" becomes "15e", not "4e", presumably because the apostrophe was removed after, not before, replacing the Roman numerals with Arabic numerals. However, there is not an obvious reason why Randall removed the apostrophe; in addition, this makes the word "i've" look like "xve".)

Irony arises from the claim of "virtual perfection", as there are problems with this encoding.

One problem with the encoding is that the double L in "virtually" is replaced with 100. This technically obeys Roman numerals' rule of adding the value of a letter to the value of an equal-valued letter just to its right (50+50=100). However, this addition rule should not apply, since in standard Roman numerals, a single number should never have multiple Vs, multiple Ls, or multiple Ds, e.g., 100 should be represented only by C (100), not LL (50 50). This would mean that a simplistic decoding script would erroneously decode "6rtua100y" to "VIrtuaCy", not "VIrtuaLLy". Thus, this string encoding system is not actually perfect. It loses information.

Another problem with the encoding is that only a very small subset of the source text can be affected by this encoding: 7 letters of 26 letters for English (the language that the text is written in) and no non-alphabetical characters.

Alternative decodings[edit]

Until the modern codification in general use today, Roman numerals weren't standardised that much, so "LL" could have been a tolerated alternative to "C". For more on that, see Classical Roman numerals. However, having the decoding script use that alternative would not solve the problem but instead would make the decoding script replace Cs with LLs instead, e.g., "delloding sllript".

One could also separate the L's into individual numbers, to become "virtua5050y", except this produces even more problems

because 5,050 is actually MMMMML and "virtuammmmmly" is definitely not an English word. (Citation: look up "virtuammmmmly" on Wiktionary.)

#2638: Extended NFPA Hazard Diamond

June 27, 2022

KNOW YOUR EXTENDED NFPA HAZARD DIAMOND:

FLAMMABILITY — 0

HEALTH HAZARD — 4

INSTABILITY/REACTIVITY — 2

NUMBER OF DIGITS IN THE STREET VALUE ($/GRAM) — 2

HOW MUCH OF A HASSLE IT IS TO DISPOSE OF — 4

(SPECIAL HAZARD)

NUMBER OF FEDERAL AGENCIES WHO WANT TO KNOW IF YOU HAVE ANY — 3

HOW MANY TIMES YOU HAVE TO SCRUB YOUR HANDS AFTER TOUCHING IT BEFORE THEY STOP SMELLING WEIRD — 1

NUMBER OF TIMES IT'S CAUSED ONE OF THOSE TERRIFYING LAB ACCIDENTS THAT CHEMISTS TELL SCARY STORIES ABOUT LATE AT NIGHT — 2

With most labs, the hushed horror stories are about something like dimethylmercury or prions, but occasionally you'll get a weird lab where it's about the soda machine or the drop ceiling.

Explanation

This comic depicts an extension of the National Fire Protection Association's NFPA 704 Standard System for the Identification of the Hazards of Materials for Emergency Response "fire diamond" emblematic insignia used to warn about the properties of hazardous substances inside a building, vehicle, room, cabinet, or container that are important during an emergency or accident, such as a fire, earthquake, spill or leak, bringing the diamond from 2x2 squares to 3x3 by adding five variously useful and humorous squares along the bottom edges. NFPA Hazard Diamonds have also been mentioned in 868: Nolan Chart.

The numbers in a normal NFPA 704 diamond do not specify values of substances' properties, but rather broad categories designating characteristics of the substances of greatest interest to first responders and hazardous materials cleanup crews. Randall's expanded diamond breaks with this convention, with several squares (Lilac, Orange, and Black) denoting absolute values, and one square (Green) denoting an economic value. This could very easily lead to documentation update headaches, especially since the Green square is mostly determined by supply and demand, and the Lilac square is linked to political outcomes. See explanation for each field in the extended square below in the table.

The only easily identifiable substance which could likely meet the specific insignia numbers shown in the comic is

thionyl chloride (SOCl2), a chlorinating reagent and solvent regulated as a chemical weapons precursor and sometimes used in the production of methamphetamine, which would also be represented with the W symbol inside the white square, indicating reactivity with water.

The title text (which references "scary stories" of the Black square) refers to dimethylmercury and prions. Dimethylmercury, C2H6Hg, is an organic form of mercury with an NFPA score of 4-4-3 (contact can be fatal, will burn below 73° F (22 °C), will combust if put under pressure). In 1997, an American chemist, Karen Wetterhahn, died 298 days after a few drops of C2H6Hg on her latex gloves were absorbed into her hand through the gloves, causing fatal mercury poisoning. Despite her having followed all safety protocols of the time, it was not then understood that the chemical was so toxic, nor that latex was so permeable to it. Prions are misfolded proteins that are responsible for a number of neurodegenerative diseases, including mad cow disease and chronic wasting disease in non-human animals and Creutzfeldt-Jakob disease in humans. These would indeed be the kind of substances that would scare those working with them in their labs; if an accident occurred, the results could be calamitous. See for example the case of Émilie Jaumain, a lab technician who died after accidentally coming into contact with prions in mouse tissue.

But a few labs have apparently had accidents involving a soda machine or dropped ceiling. The latter may be a reference to the death of Janet Parker: One inquiry

found that she was infected with smallpox when a sample traveled upward from a lab on the floor below hers; however, other investigations have challenged that finding. There are occasional instances of vending machines causing injury or death, usually caused by people trying to shake or tilt the machines to get product out and having the machine tip and fall on them. On average, a couple of Americans per year are killed in this way. Reagents obtained in this way tend to have more impurities than those usually used in labs, but are relatively safe to shake.

Table of extended diamond[edit]

#2639: Periodic Table Changes

June 29, 2022

It's nice how the end of the periodic table is flush with the edge these days, so I think we should agree no one should find any new elements after #118 unless they discover a whole row at once.

Explanation

The periodic table is a table used to arrange chemical elements according to their chemical and physical properties. This comic proposes "changes" to the periodic table that would be more pleasant aesthetically or make the periodic table look more regular. Some of these are (somewhat) practical changes to element abbreviations that could improve clarity in English, though changing documents to use different abbreviations would probably be more trouble than it's worth. However, other changes move elements around without considering that elements would stop being arranged by their properties. The periodic table would stop being useful after such changes unless said changes were meant to physically change the material properties of the elements, which would be impossible, although the comic plans to solve the problem with "free training" to their atomic behavior.

Other modifications make up new elements or remove existing ones from the table, which would not be a reasonable decision given that the periodic table is supposed to include all existing elements, whether they make the table neater or they don't. See explanation for the proposed changes in the table below.

The title text suggests discovering elements only in entire rows at once, a suggestion which is far more unreasonable than it appears on its surface. Elements with more protons than 118 could be discovered in

future by collisions in particle accelerators, but as of right now, the chances of finding or synthesizing samples of such elements lasting longer than 10 quadrillionths (10−14) of a second is looking rather grim. Furthermore, the theoretical 8th period is expected to contain 50, more than any row in the current 7-period table. Taking this all into account, discovering an entire row's worth of elements all at once is nothing short of a herculean undertaking, and its difficulty only grows in orders of magnitude for each successive row. With all that said, however, elements beyond 118 are unlikely to have practical applications in science and engineering due to their vanishingly short lifespan and may probably only ever serve as intellectual curiosities. Thus, refraining from updating the periodic table prior to the discovery of the entire 8th period is not a terrible sacrifice to make in the name of preserving the table's visual aesthetics (provided data of new elements are recorded and catalogued in other ways).

This is another comic containing red annotations over a complex and established structure. It suggests changing the periodic table, which was also discussed in 2214: Chemistry Nobel.

Table of the proposed changes[edit]
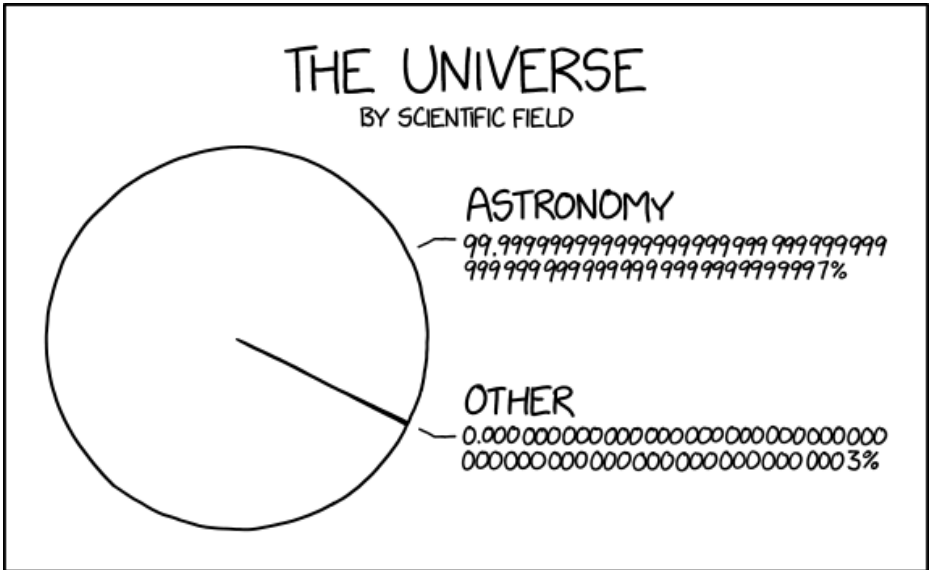
The math and philosophy people also claim everything, but the astronomers argue that the stuff they study really only comprises a small number of paper surfaces.

Explanation

Astronomy is the study of outer space and celestial phenomena. This comic makes a joke that most of the "universe" falls under the study of astronomy, which makes sense because it is so vast and large and is not studied directly by other fields of science.

The volume of the observable universe is 3.566×10^{80} cubic meters. The volume of Earth is 1.08321×10^{21} cubic meters. 1.08321×10^{21} m3 ÷ 3.566×10^{80} m3 × $100\% \approx 3 \times 10^{-58}\%$, which is scientific notation for the second of the two percentages, the first being its difference from 100%.

Thus, the universe is comprised almost entirely of the objects of astronomical study, when measured by volume. There are many arguments to be made that this is not the most useful way of measuring the size of scientific fields compared to the universe. Other arguments include:

- Astronomers are only studying the observable phenomena (i.e. light, subatomic particles, and gravity) of the rest of the universe, leaving the vast majority of the universe's properties (for instance the geology and biochemistry of an unknown planet in a distant galaxy) entirely unstudied.
- Astronomy is only possible due to understanding of physics, optics, chemistry, mathematics, and geometry, so surely they deserve some credit.

- The interesting parts of the universe are not the empty space.

They are the matter and energy described by physics and chemistry.

They are the life experiences of people, which are overwhelmingly terrestrial even for professional astronomers (who often complain about how little time they can allocate to making actual astronomical observations).

- It is disingenuous to claim to be studying more than every other field when astronomy and astrophysics publications amount to only about 0.5% of academic science and engineering output worldwide. Other fields may be studying smaller things, but they are studying them much more thoroughly.
- Emptiness has less information and is less interesting than non-emptiness; therefore geometric volume is only very weakly correlated with useful information.

A counterargument is that astronomy, cosmology, and astrophysics are the only scientific disciplines that study the Big Bang and subsequent inflation from which all matter, energy, and space itself arose. The ordinary laws of physics can describe neither of those events.

The title text says that mathematicians and philosophers claim that what they study also represents everything. But (according to the comic) astronomers counter this by saying that they just study things that are written down, and this comprises just tiny amounts of "paper"

on the Earth. This claim by mathematicians also appears in 435: Purity. A conceivable counterargument by philosophers could be that any and all science, including astronomy, is nothing more than a branch of epistemology, the philosophical study of knowledge. Another could be that since philosophy includes theology, it is studying something even larger than the universe (although one could argue back that theology is nothing more than writing fiction, and yet again just a study of pieces of paper.)

#2641: Mouse Turbines

July 04, 2022
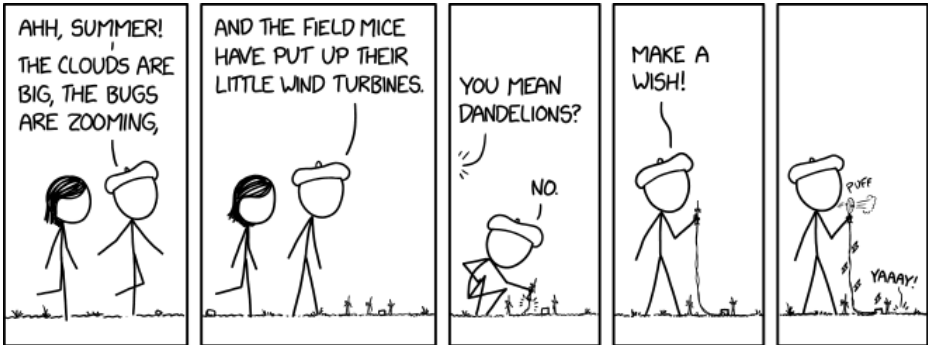
It's sad seeing those videos of turbine blade being torn apart in high winds, but it's the only way they can disperse their seeds.

Explanation

Beret Guy and Megan are walking during the summer, where Beret Guy expresses his appreciation for typical features of a summer day. Though, considering the rest of the comic, Beret Guy could mean there are large (or popular) server farms somewhere and that the bugs are video chatting. He also mentions "wind turbines" put up by field mice, which Megan initially assumes to be referring to dandelions (similar to the wordplay that Beret Guy utilized in 1322: Winter.) However, Beret Guy turns out to be speaking literally, as he picks up what is in fact a tiny wind turbine, says to make a wish, and blows into it. This causes the blades of the turbine to spin rapidly, generating a lot of power for the structure it is connected to, thus causing a field mouse to cheer in excitement.

The comic was published on the 40th anniversary of the film release of The Secret of NIMH, a story featuring field mice and rats who escaped from a lab experiment which left them with a similar intelligence to human beings. The story takes place as the rats strive to achieve self-sufficiency, so that they no longer need to steal power from human-built electrical lines. (The novel this film was based on, Mrs. Frisby and the Rats of NIMH, describes the experiments and the rats' struggles in more detail.)

The title text builds on the similarities between small wind turbines and dandelions by claiming that turbines

reproduce by dispersing their blades, in the manner of dandelion seed dispersal. Randall's suggestion of turbine seeds conflicts with Beret Guy's assertion that the turbines were built by field mice.

Efficacy[edit]

Sadly, the power output per size of wind turbines increases with their size, a limitation not shared by other forms of renewable energy such as solar panels and pico hydro. According to this calculator, a 10 centimeter radius wind turbine powered by a 5.7 meter/second breath would produce one watt at just 26% efficiency.

Further frustrating mouse use of wind power, windspeed increases logarithmically with height above ground. Windspeed is reported as its value 10 meters above ground, where it is 1.5 times faster than at ground level. In the U.S., where Randall lives, average year-round windspeed is about 15 km/h, or about 2.8 m/s at ground level, yielding only 0.11 watts from such turbines. However, a typical adult mouse weighs 25 grams, compared to about 81 kilograms for humans in the U.S., so we could estimate that mouse electricity needs would be about 0.03% of people's.[dubious] The average U.S. residential customer uses 1,242 watts of electricity, 0.03% of which is 0.37 watts. Therefore, the three turbines visible in this comic could serve about 89% of a mouse's needs. While this figure does not account for necessary home energy storage efficiency (92.5% for the Tesla Powerwall) overhead, mice usually live much less extravagantly than typical Americans,[citation needed] so three turbines per mouse should be sufficient.

#2642: Meta-Alternating Current

July 06, 2022

CURSED CONNECTORS #120

INVERTERS

RECTIFIERS

META-ALTERNATING CURRENT EXTENSION CORD
(ALTERNATES BETWEEN AC AND DC)
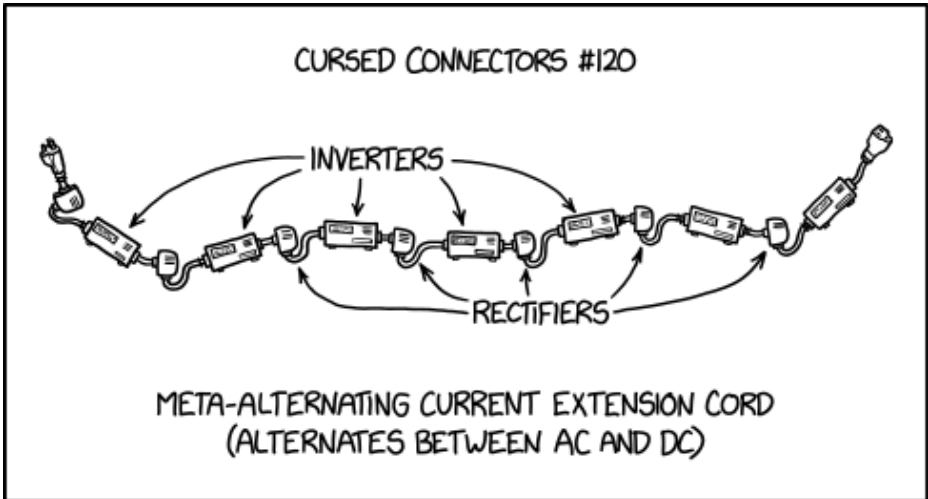
It's always bothered me that you can't cancel out an inverter by putting a second inverter after it.

Explanation

This is the sixth installment in the series of Cursed Connectors and presents Cursed Connectors #120: Meta-alternating current extension cord. It follows 2589: Outlet Denier (#78) after about 4 months and was followed about 1.5 years later by 2880: Sheet Bend (#46).

Direct current is a unidirectional flow of electrons from a power source to something being powered, through one or more conductors, before returning to the power source via one or more other conductors, thus completing the circuit. Batteries produce direct current. It is commonly used in electronics applications, including computers. Alternating current, on the other hand, frequently reverses the direction of electron flow, and is commonly used for longer-distance transmission (such as from the power plant to an outlet).

This comic proposes a humorous Meta-Alternating Current, which uses a series of adapters to "alternate" between DC and AC current along the length of a connector. This is absurd in part because typical power inverter efficiency is 90%, and maximum bridge rectifier efficiency is about 99% for 120 V,[actual citation needed] so an extension cord made in this manner would lose about 11% power (compounded) per such pair. For the wire shown in the comic, with seven pairs, the efficiency would be 0.89⁷, which is 0.45, that is, 45%.

The title text bemoans that an inverter, which converts

direct current to alternating current, does not work in the other direction, as a layman's interpretation of the word "inverter" might assume. Rather, a separate device, a rectifier, also pictured in the comic, must be used for this second conversion. (However, a similar circuit to an inverter may be used to rectify in a process called active rectification.)

30,000 NEUTRINOS
FRESHLY PRODUCED

PLUS 4 ZEPTOGRAMS
OF DARK MATTER
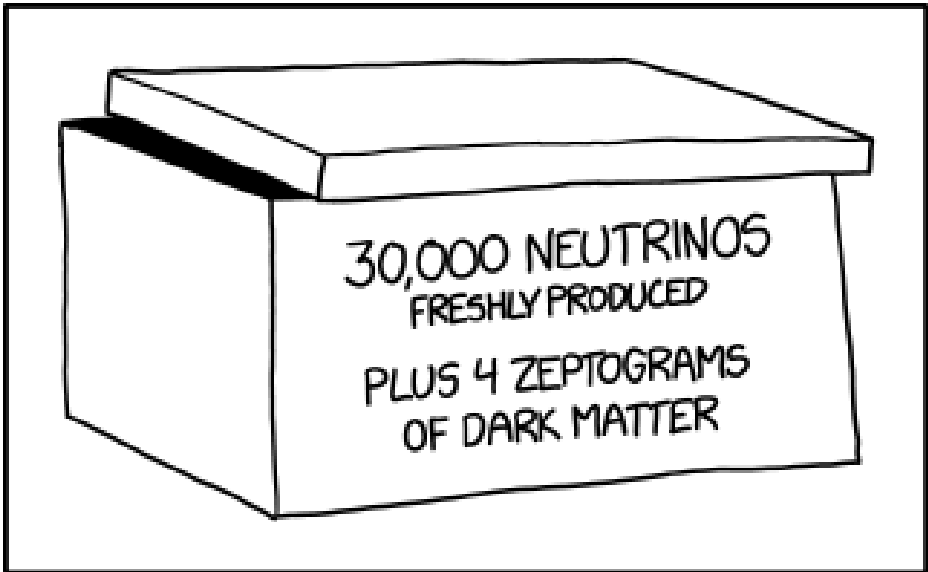
COSMOLOGISTS ARE EASY TO SHOP FOR BECAUSE YOU CAN JUST GET THEM A BOX.

These neutrinos were freshly produced by a local source just 8 minutes ago

Explanation

This comic shows a box labeled to indicate that it contains 30,000 fresh neutrinos and four zeptograms of dark matter. The box is intended as an inexpensive gift for a cosmologist. The gift giver didn't put those things in the box—both are simply passing through it, so the "gift" consists of exactly what was in the empty space it occupies. While the caption suggests this would be a good gift for a cosmologist, what they or anyone else would do with such a box is uncertain.

There are about a billion neutrinos per cubic meter throughout space, produced during the Big Bang. However, the flux of "freshly produced" solar neutrinos at Earth is around $6.5 \times 1010/cm2/s$, yielding about 2.1 million per cubic meter, and implying the box is around 12 liters, three quarters as big as a typical breadbox.

Four zeptograms is a minuscule mass, equal to four sextillionths of a gram, the mass of about 200 carbon-12 atoms or around 20 to 23 amino acids. There is an estimated 0.011 to 0.016 solar masses of dark matter per cubic parsec local to the solar system, or about 900 zeptograms per cubic meter, suggesting the box is closer to 4 liters. This discrepancy could imply Randall agrees with cosmologists who believe dark matter is partially composed of primordial black holes, instead of being composed entirely of ubiquitous subatomic particles. This comic coincided with the first James Webb Space Telescope science image release to the public containing

gravitationally lensed very distant quasars and population III stars, the spectra of which can be used to test certain hypotheses associated with dark matter being black holes. A billion neutrinos have a mass of only about 2×10-12 zeptograms, at about 0.1 electron volts each.

The "local source" mentioned in the title text is a joke about the commercial value of fresh, locally produced items, but the comic means that the neutrinos come from the Sun. It takes solar neutrinos slightly more than 8 minutes to reach Earth once they're emitted, roughly the same time as photons take to make the trip. (While energy takes approximately 170,000 years to reach the Sun's surface from its core, where the fusion reactions occur, the neutrinos are not slowed down inside the Sun and travel at about 99.9999999999% of the speed of light. Thus, they will have aged by less than a millisecond, and so are technically even fresher than indicated.)

#2644: fMRI Billboard

July 11, 2022
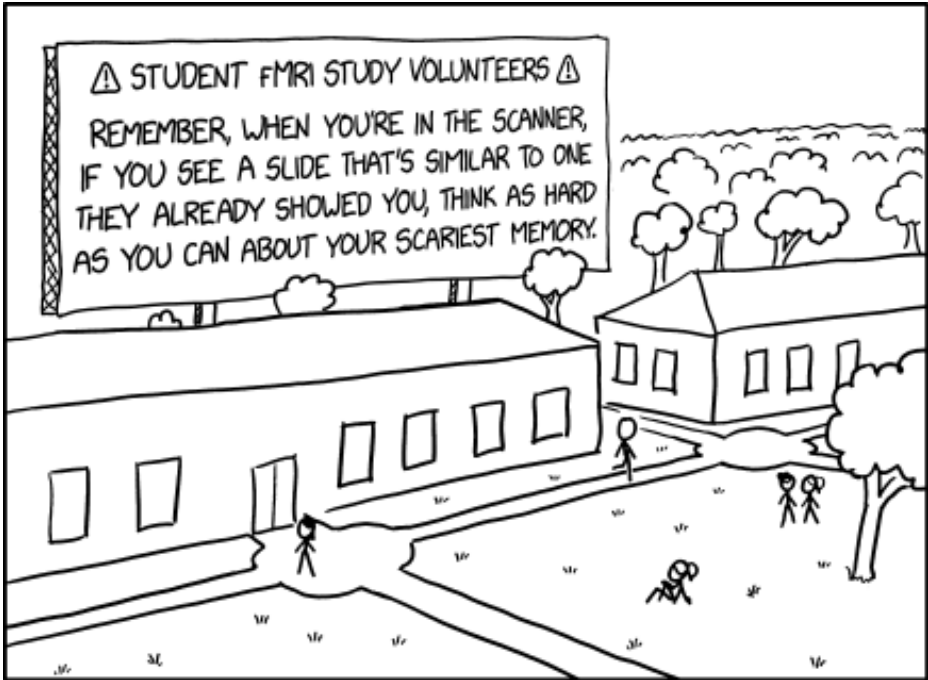
A RIVAL NEUROSCIENCE DEPARTMENT KEEPS
TRYING TO SABOTAGE OUR EXPERIMENTS.

[other side] If the first word of an instruction you're
given starts with the same letter as your crush's name,
for that step imagine the experimenter is your crush.

Explanation

Functional magnetic resonance imaging, or fMRI, is a method of imaging brain activity by detecting blood flow changes apparent from magnetic differences between oxygenated and deoxygenated hemoglobin. Scientists use fMRI to try to detect deception and false memories, plan brain surgery, and understand the relationship between brain structures and cognition, among many other investigations. Volunteer research subjects participate in such studies by lying inside large toroidal scanners while conducting tasks with projected images, sounds, and the like.

This comic shows a billboard erected by a neuroscience department in an attempt at sabotaging a rival department's volunteer subject compliance with their fMRI study instructions, by suggesting behaviors which would likely produce unexpected results, such as recalling a frightening memory after seeing similar stimulus slides, or imagining the lab technician is a romantic interest when reading words that begin with the same letter as their name. This is funny because academic department rivalries do not usually lead to sabotage,[citation needed] and in the rare cases when they do, it's usually clandestine instead of so absurdly blatant. The comic also shows neuroscience in terms of the technologies used to study it, and how experiment instructions can influence its development.

Following such suggestions or even inadvertently

remembering them during an fMRI could very well interfere with its results. fMRI experiments are often criticized because they have low statistical power and can easily be confounded by experiment subject error in following instructions, among many other variables. In a famous 2009 study, a dead fish was shown to have apparent evidence of brain activity when scanned with ordinary fMRI techniques. In 2015, discovery of a statistical error invalidated at least 40,000 fMRI studies. Subsequently in 2017, many more fMRI results were further discredited due to poor software parameter selection.

The title text indicates that the sabotaging instructions are printed on both sides of the billboard, suggesting that it might have been erected on the grounds of the targeted rival department. Alternately, the instructions on the other side may be intended to disrupt research at the other institution.

#2645: The Best Camera

July 13, 2022

The best camera is the one at L2.

Explanation

The Best Camera Is The One That's With You is a book by photographer Chase Jarvis, celebrating mobile phone cameras, not for their technical quality, but rather for the fact that people usually have them when interesting subjects appear. This advice is often given to novice photographers; sometimes phrased as, "The best camera is the one you use most." A cheap camera is better than an expensive professional camera if it is more often with the photographer, for example if it is light-weight enough to be carried on hiking trips. A fancy expensive camera that isn't available to use is of no value for taking pictures.

In this case, however, "the best camera" refers to the James Webb Space Telescope (JWST), the spacecraft depicted in the third panel, which cost $10 billion—$9.5 billion over budget—and was fifteen years late. It can be considered a camera because it takes pictures, and it's the best space telescope to date in terms of aperture size and thus angular resolution. The first pictures taken by the telescope were released on 11-12 July 2022, a few days before this comic was published. The pictures from JWST show objects as they were as much as 13.1 billion years ago, which is unprecedented by space telescopes, although further objects have been identified by terrestrial telescopes. The telescope has three instruments that can act as "cameras" for imaging, a fourth spectrometer instrument, and many dozens of optical filters. Because the telescope can only take infrared

photographs invisible to the human eye, each of the filters has been assigned a standardized visible color to convert images for viewing. However, astronomers are encouraged to use other color schemes when observing a limited portion of the filters' range or rendering interferometry, and to convert very distant objects to their original color from redshifted infrared when possible. The capabilities of the JWST are likely to soon answer many difficult astronomical, astrophysical, and cosmological questions that had been previously undecidable, including important questions about the biosignatures of exoplanets.

The title text references Lagrange Point 2 (L2). The Lagrange Points are five locations corresponding to stationary regions of the restricted three-body problem, in which one of the bodies is much less massive than the other two. A low-mass body in one of those five locations will remain roughly stationary relative to the other two bodies with very little fuel needed for trajectory corrections. In this case, the JWST orbits around the L2 point of the Earth-Sun system with a period of about 6 months, rather than being stationed exactly at it, to avoid shadows from the Earth and Moon that would cause harmful temperature and power variations. Thus it avoids the problem with the Hubble Space Telescope caused by orbiting the Earth, allowing only a short observation window per orbit, with only about 55 minutes of each of its 95 minute orbits usable for observations not sufficiently above or below its orbital plane.

#2646: Minkowski Space

July 15, 2022
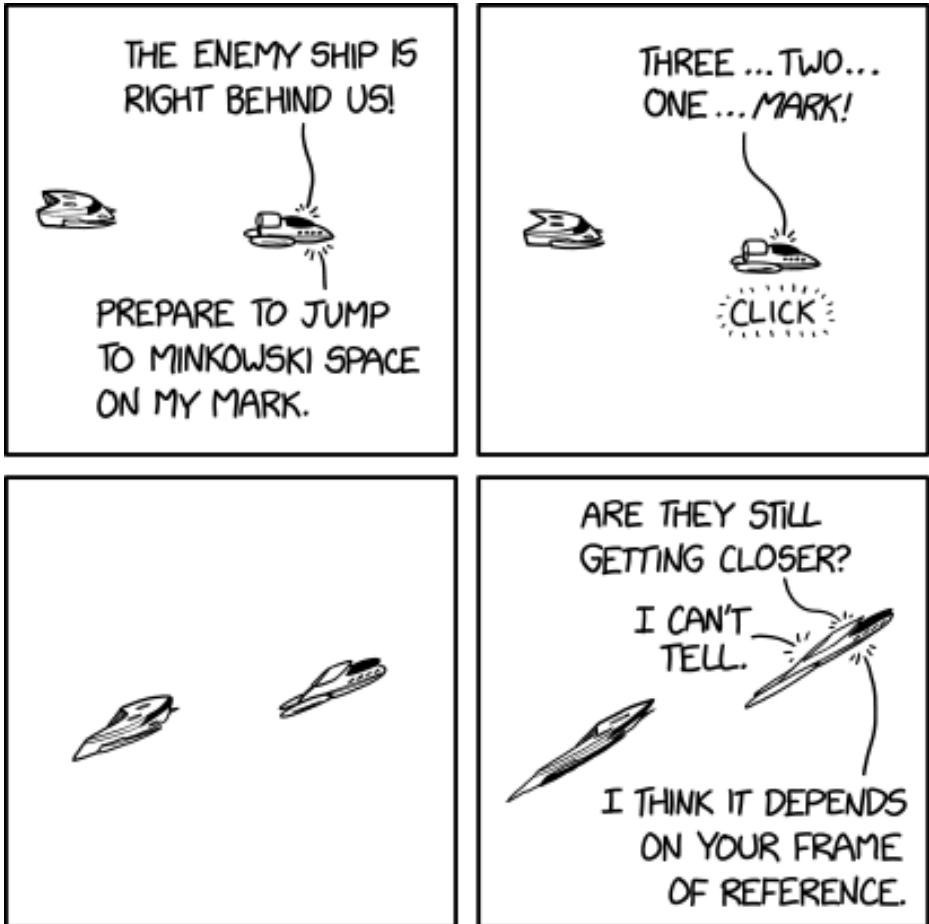
My liege, we were able to follow the ship into Minkowski space, but now they've jumped to Hilbert space and they could honestly be anywhere.

Explanation

Faster than light travel, an impossibility in our universe, is often portrayed in science fiction by having spaceships enter (or "jump") into some different realm, termed "hyperspace" or similar technobabble, where superluminal travel can occur before returning to the ordinary universe. In this comic, a spaceship is being chased by an enemy ship and the crew attempt to escape by jumping into Minkowski space which is actually just conventional 3-D space together with time combined into a mathematical object called a manifold used in special relativity. Because Minkowski space is merely a representation of real physical spacetime, "jumping" into it is meaningless and offers no benefit for escaping pursuit, providing the humor of the comic's absurdist joke.

The visual depiction of the spaceships skewed diagonally is based on the graphical Minkowski diagram representation of objects in Minkowski space, where the world line of matter is bounded inside its diagonal light cone.

The mention of distance depending on the observer's frame of reference refers to distances changing when measured in different inertial frames of reference, a concept called the relativity of simultaneity. Here are some videos intended to explain that concept. The skewing depicted changes the distance between the spaceships in such a way that the tip of the pursuer

comes closer to the pursued spaceship, but their centers move further apart. So the question of whether they have come closer is indeterminate for the reader of the comic.[citation needed]

The title text is a status report from someone in the pursuing spaceship to their leader (whom they call "my liege.") Following the spaceship to Minkowski space was not a problem, but the pursued ship subsequently jumped to Hilbert space and could now be anywhere. Hiding in Hilbert space is much easier because Hilbert spaces (of which there are many very different varieties, unlike Minkowski space) can have an infinite number of dimensions, and are thus much more complicated than four-dimensional Minkowski spacetime.

A similar situation happened in 2577: Sea Chase, where instead of jumping from space to space, ships jumped from map projection to map projection.

#2647: Capri Suns

July 18, 2022

YOU KNOW, THESE CAPRI SUNS ARE GOOD, BUT THEY'RE *REALLY* SALTY.

I THINK THE HOSPITAL MAY BE STARTING TO REALIZE THAT I'M NOT ACTUALLY A DOCTOR.

[As security is dragging me away] "Come on, at least I didn't make the mistake in the other direction!"

Explanation

Cueball has been impersonating a doctor at a hospital. But his attempt to fool the staff (including Megan and Doctor Ponytail) fails when he mistakes a saline bag (as labeled when zoomed in) for a Capri Sun juice drink.

Capri Sun is a fruit juice concentrate beverage that comes in soft rectangular Mylar bags with a small seal near the top, to be pierced with an included straw so as to sip the drink. Saline bags, used in hospitals and other medical settings, are also soft and rectangular, with an intravenous (I.V.) drip connection about the same size as such straws, and usually contain a 0.9% sodium chloride (table salt) solution in sterile water so they are salty enough to be isotonic with blood. Capri Sun is mostly sugar water, and only 0.00008% salt, so it tastes sweet instead.

Almost everyone would be very unlikely to accidentally mistake saline bags for Capri Sun, especially a medical doctor.[citation needed] Cueball begins to realize that his attempt to impersonate a doctor has derailed when the hospital staff notice that he made such an absurdly unlikely and therefore humorous error.

The title text makes it clear that Cueball is being removed from the hospital by security personnel. While they are dragging him out, he tries to point out that drinking saline is better than putting Capri Sun into a patient's I.V. drip, as it would endanger the patient, arguing that

this mitigates the severity of his transgression. The guards apprehending him are unlikely to be persuaded, as impersonating hospital staff is a serious offense with dangerous risks and severe consequences. In Massachusetts, where Randall lives, the unlicensed practice of medicine can result in a maximum $1,000 fine, up to a year in prison, or both.

The comic arguably continues 451: Impostor and 699: Trimester.
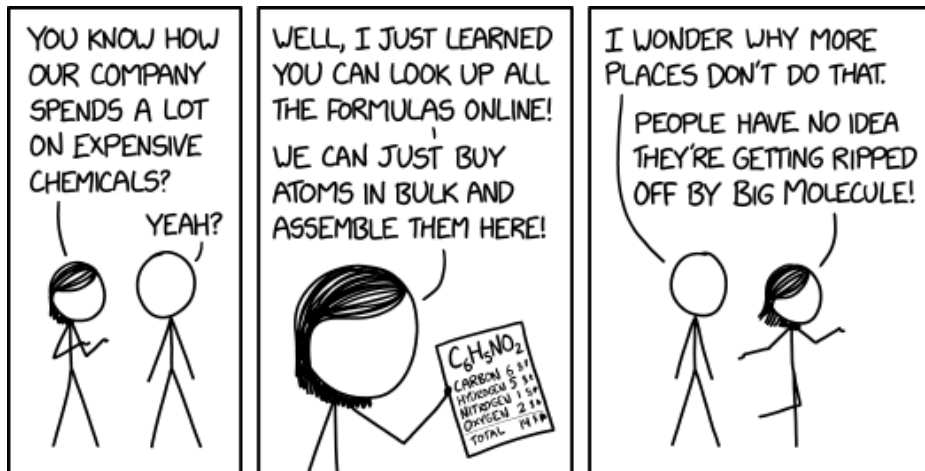
It's hard to believe, but lots of kids these days ONLY know how to buy prepackaged molecules.

Explanation

In this comic, Megan mentions to Cueball that their company spends a lot on chemicals for which you can find formulas online. She suggests assembling chemicals from atoms "bought in bulk," holding a sheet of paper with the empirical formula C6H5NO2, which designates hundreds of compounds including nitrobenzene, niacin, isonicotinic acid, and picolinic acid, followed by their component elements listed with quantities and prices. The ambiguity of chemical formulae is one of the jokes in the comic.

While many expensive chemicals are composed of inexpensive and easily available elements, "assembling" those elements into specific molecules is rarely as simple as Megan implies. That work is the primary purpose of the global chemical industry. In-house chemical synthesis is usually not cost effective, because end users have limited time and are generally unable to leverage the economies of scale inherent in bulk manufacturing by specialist industrial firms. They are also not able to benefit from synergies by simultaneous synthesizing different compounds. However, we don't know whether Megan and Cueball work in a laboratory, factory, or some other industrial setting. If they need chemicals in bulk, or only very small quantities, synthesizing them might be cost effective. In any case, producing chemicals from their constituent elements, or — as is far more common — precursor compounds, is difficult and time-consuming, usually requires expensive equipment,

and is often fraught with peril. It's conceivable that this could change as biotechnology, artificial intelligence, and nanotechnology develop, but it is a far fetch given the relative ease of synthesizing chemicals from other chemicals. Nitrobenzene, one of the $C_6H_5NO_2$ compounds, is an excellent example because it is explosive and extremely toxic, and its synthesis is highly exothermic, making it one of the most dangerous syntheses in the chemical industry. Such issues answer Cueball's question as to why more places don't manufacture their own compounds from atoms. Megan seems to be imagining synthesis as a much simpler process without reactivity, energy release, or hazardous intermediate substances. The characters' naivety also gives rise to the humor of the comic.

"Big Molecule" is an industry nickname like Big Oil or Big Pharma, amusing in its own right, and conceivably implying that the chemical industry is conspiring to prevent end users from synthesizing their own compounds. Big Oil and Big Pharma are real industrial nicknames, referring to large industries run by a relatively small number of massive and hugely profitable companies. These companies are sufficiently wealthy and influential that they exert significant control over the marketplace, and even over government policy. Consequently, many consumers believe that their influence allows them to price products unfairly and prevent competition. "Big Molecule," on the other hand, is not a common term. It could be used to refer to the global chemical industry, but that industry is neither seen

as being excessively powerful, nor does it impact consumers as visibly, and so doesn't merit a similar nickname. Literal big molecules tend to be more difficult to synthesize than little ones, with the difficulty increasing more rapidly than the size. Some big molecules such as synthetic DNA are constructed chainwise from sub-units, and in these cases the difficulty is (approximately) linear with size.

Megan is holding a note listing how many of the four types of atoms she needs to build one molecule of the compound she wants to assemble. The paper seems to list prices for buying 6 carbon, 5 hydrogen, 1 nitrogen and 2 oxygen atoms, although the units aren't specified and the very small prices are illegible. At the bottom is a sum showing she needs 14 total, again with an illegible price. She is suggesting buying atoms in bulk, which should be even cheaper than buying them individually. However, this is another layer of humor, as you can neither buy individual atoms or get a price for them, showing her lack of understanding of chemistry. An actual bill of materials for a chemical compound synthesis from constituent elements alone would list the elements converting their number of atoms to moles, then to mass for solids and some fluids or to volume at the available pressure and temperature for other fluids, and then to the purchase price, which would usually need to be rounded up to match the next largest size available from suppliers. Also reagents are usually necessary for syntheses, e.g., reactants, solvents, buffers and catalysts such as enzymes. These can cost more than the compounds' constituents

but are sometimes recoverable for reuse, though that may require using additional reagents. In many cases, the cost of the elements would be more than the cost of the compound. For example, purchasing hydrogen and oxygen from which to make water would cost more than water costs.

The title text refers to the fact that older people often complain that "kids these days" don't know how to do things that seemed fundamental to past generations. Randall may have expressed that he dislikes other statements like these in previous comics. It may also refer to the decline of home chemistry sets popular from the late 1700s through the early 1980s that encouraged kids to experiment with basic chemical reactions like generating esters or polymers, or the even older decline in home manufacture of gunpowder as was common in the 1800s. Chemical engineering was more widely practiced during the development of plastics, but far fewer people understand how they are made today. Similarly with automobiles, domesticated crops, and many other technologies that progressed through a period of popular attention but became siloed into industries, corporations, governments, or branches of academia. This is happening now with some software, circuitry, and other technologies, where fewer people know how to build and troubleshoot complex devices and systems. Technology users thus lose their ability to build and repair machines and modify their tools themselves, having to rely on paid services instead. Similar to the makerspace movement, community chemical labs have

occasionally been cropping up, where people work together to perform citizen science, including occasional chemical synthesis, by sharing community resources; however, biohacking and structural manufacturing are far more common.

This comic may have been prompted by recent news that scientists have found a way to assemble and change atoms in individual molecules by modifying their bonds.

July 22, 2022

I got banned from the county fair for handing out Helium-2 balloons. Apparently the instant massive plasma explosions violated some local ordinance or something.

Explanation

This is another one of Randall's Tips, this time with a series of Physics Cost-Saving Tips. It also continues the previous 2648: Chemicals comic's jocular theme of tricks to supposedly save money based on misinterpretations of science.

It suggests four ways to reduce costs or provide something for free for physicists to save money on their research. For instance getting free electrons from a conductor or replacing regular helium with helium 2. None of these would provide any real advantages even when possible to implement, and could even be very dangerous, see below in the table. Obtaining money from physics experiments was also described in 2007: Brookhaven RHIC.

In the title text, Randall claims to have been banned from the county fair for handing out helium-2 balloons because of the instant massive explosions caused by its radioactive decay (that helium-2 decays fast is mentioned in the comic, with a joke suggestion to use it quickly). He jokes that the balloons violated a local ordinance. Helium balloons are often given out at county fairs and similar events, but they are filled with helium-4 and therefore inert (a very small part will be helium-3, 2 ppm). A balloon filled with helium-2 is a practical impossibility because of its nanosecond half-life. Assuming a 12-inch diameter balloon at 1 atmosphere of pressure, the balloon-bomb would have a yield of roughly 17 tons of

TNT equivalent.

The smallest nuclear bomb, the W54, had a yield of between 10 and 1,000 tons of TNT. The largest conventional bomb, the GBU-43/B MOAB, has a yield of roughly 11 tons. The 2020 Beirut explosion was roughly equivalent to 500 tons. So, while the helium-2 balloon bomb would be larger than all conventional bombs, it would still be smaller than most nukes. Handing out what are effectively small atomic bombs at a county fair would not go down well with any surviving local authorities,[citation needed] so merely being banned is a very mild punishment. Criminal charges such as mass murder and terrorism would be more likely if it weren't for the absurd impossibility of the scenario.

The title text is likely also a pun, as the word "ordinance" means a local law, and the very similar sounding word "ordnance" means artillery and other explosive weapons, which the balloon would qualify as.

Table of tips[edit]

#2650: Deepfakes

July 25, 2022

Panel 1:
THANKS TO DEEPFAKES, SOON WE WON'T KNOW WHAT'S REAL ANYMORE. VIDEO WILL BECOME MEANINGLESS.

Panel 2:
I DUNNO. WE'VE HAD PHOTOSHOP FOR DECADES AND STAGED PHOTOS FOR CENTURIES.

IT HASN'T MADE PHOTOS MEANINGLESS.

Panel 3:
THE BOTTLENECK FOR FAKE STUFF ISN'T TECHNICAL. THE BOTTLENECK IS WILLINGNESS TO LIE.

"PEOPLE LYING" IS A VERY OLD PROBLEM.

IT'S A KNOWN EXPLOIT.

Panel 4:
I GUESS TECHNICALLY WE'VE BEEN ABLE TO MAKE *TEXT* DEEPFAKES FOR 5,000 YEARS.

MAYBE EA-NASIR'S COPPER INGOTS WERE ACTUALLY FINE!

If so great a deductive mind as Arthur Conan Doyle can be fooled by the Cottingley Deepfakes, what chance do we mortals have? Soon our very reality will be dictated by the whims of Frances (9) and Elsie (16).

Explanation

A deepfake is an altered video, designed to deceive, by replacing a person in a video with someone else. White Hat believes that this technology will make it difficult to trust video evidence from now on. However, Cueball responds by saying that "fakes" have always existed, in photos (either through alterations by software such as Adobe Photoshop, or deliberately staging faked images, for example of the Loch Ness Monster) and even more so by people simply lying. White Hat comes around to Cueball's position and says that even the written word is prone to deception and lying.

Scientific studies of deepfakes have produced surprising results, suggesting that they are more likely to increase uncertainty than persuade, that their increased prevalence could inoculate the public against disinformation, and that they are more likely to be shared because of their humorousness than persuasiveness. Other studies have found that deepfakes are persuasive, especially among those who are unfamiliar with them.

The complaint tablet to Ea-nasir is a 3,800 year-old clay tablet containing the oldest known written complaint, in which a customer complains to a merchant, Ea-nasir, about the quality of his copper ingots. Cueball's last statement says that perhaps this complaint could have been a lie to begin with, and there was nothing wrong with Ea-nasir's wares. This supposition is arguably the humor of the comic, apart from the hyperbole of the title

text.

The title text references the Cottingley Fairies, a series of five photographs produced in 1917 by two children, Elsie Wright and Frances Griffiths, who were 16 and 9, respectively. The photographs appear to show the children playing with fairies in their garden. The photographs received widespread attention when Sir Arthur Conan Doyle, the author of the Sherlock Holmes stories, used the photos as proof of paranormal phenomena in a 1920 magazine article. Conan Doyle was noteworthy for being a strong proponent of reaching conclusions based on evidence and reason, and also held a deep belief in paranormal and supernatural phenomena. In 1983, Elsie and Frances finally confessed that the photos had been faked, by the simple process of making and posing cardboard cutouts traced from figures in a children's book with wings added. Due to technical advances, young children now can more easily create convincingly realistic fakes,[actual citation needed] but similarly there are many more self-styled 'experts' willing and able to dedicate themselves to 'proving' one or other side of any argument about authenticity.

A similar dilemma was alluded to in the 1958: Self-Driving Issues comic, where technology does not create a new way to lie, but may make certain lies more convincing to some parties, such as self-driving cars in that comic.

#2651: Air Gap

July 27, 2022
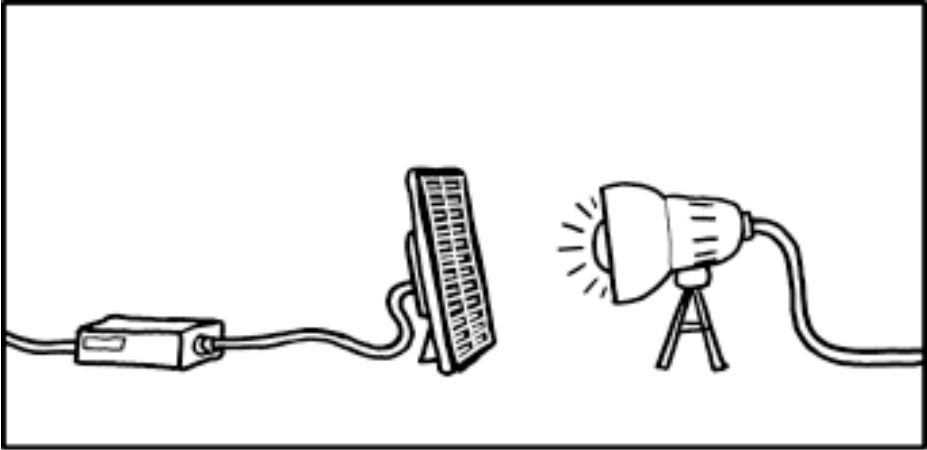
ENERGY TIP: INCREASE THE SECURITY OF YOUR HOME POWER SUPPLY BY INSTALLING AN AIR GAP.

You can still do powerline networking, but the bitrate does drop a little depending on the lightbulb warmup and cooldown delay.

Explanation

This is another one of Randall's Tips, this time an Energy Tip. The comic conflates the concepts of computer network security and home electrical power safety to comical effect, resulting in a deeply impractical and ineffective proposed solution. In computer security, air-gapping is a measure used to secure sensitive computers or networks of computers by isolating them from the broader internet, since computers are often breached through the internet.

Randall suggests increasing the security of your home power supply by air-gapping it, using the light from a powered lightbulb to power a solar panel which then supplies power to the home, such that there is no physical wired connection between your house and the public electricity network. This is a large and very inefficient version of an opto-isolator, but would protect equipment behind the solar panel from power surges such as lightning strikes (which in an improperly grounded home could blow out the light bulb, but not so easily risk frying the equipment beyond the photovoltaic cell and its inverter). Due to its inefficiency, this approach would waste substantial amounts of energy. Optical power beaming is being investigated to recharge drones in flight.

The title text mentions that a computer can still be connected to the internet via the power supply by using powerline networking, but that the bandwidth would be

reduced by the lightbulb's warmup and cooldown delay, which would reduce the signalling rate the lightbulb could accomplish to no more than hundreds of bits per second, if that, for incandescent bulbs. However, as the light bulb cannot pick up any signals (possibly) emitted from the solar panel, the unidirectional link would be useless for traditional networking, because essential requests and acknowledgments would be unable to travel from behind the solar panel to the lightbulb. Early communication satellite systems for data networking used high-bandwidth unidirectional downlinks paired with low bandwidth ground telephone lines for outbound transmission, but such network configurations remain very uncommon.[citation needed]

Randall's solution is of course a joke. But in reality he could have used isolation transformers, which serve to allow the transfer of power via changing electromagnetic fields without an electrically conductive path. Most transformers, including "wall wart" power adapters, provide this form of isolation and protect devices from noise, voltage transients, most surges, and shock hazard, using fuses and other circuitry. They also limit powerline networking bandwidth by filtering out high frequencies. One relatively obscure way this comic is funny involves the relationship of the two concepts being conflated. Power analysis in computer security is a form of side-channel attack where the attacker observes and/or manipulates the power use by a device for some reason — for example, to gain insight into an otherwise protected process, or to exfiltrate information without

having to use a monitored network connection. Power analysis in fire safety means measuring the power factor, watts, resistance, inductance, capacitance, volts, and amps of electrical circuits.

The look and subject of this comic is reminiscent of the Cursed Connectors series. But without the numbered cursed connector in the comic, this is not one of those connectors.

Why this would be inefficient and impractical[edit]

- Even energy-efficient LED lightbulbs are only about 35% efficient at turning electricity into light, with the rest emitted as heat.

- The air gap is inefficient at passing light from the bulb to the panel, causing some of the light from the lightbulb to be lost to places other than the solar panel, such as to the eye of the observer. A rough guess might be that in the configuration shown less than 60% of light produced will reach the panel, even assuming a perfect reflector.

- Solar panels are generally around 20% efficient at converting light into electricity, with claims at the world record from a single light source at around 40%.

All these efficiency-reducing factors, and others, multiply together. Therefore, only a small fraction of energy would be transmitted between the two ends of the air gap, making the circuit require much more electricity and be much less cost-efficient. For instance, the generous assumptions above lead to 96% of the power being lost. The solution as illustrated shows a single apparently-normal lightbulb, which typically draw no more

than 250 watts, and usually much less power. Given the above efficiency issues, it would provide less than a tenth as much power.

How this could have a theoretical benefit[edit]

In electrical engineering, galvanic isolation is a measure to prevent an electric current flow between two circuits, instead, signals and energy are exchanged through indirect methods, e.g. magnetically, optically, or wirelessly. This is used to isolate a dangerous high-voltage circuit from the rest of the device, ensuring equipment and personal safety, it's also used to isolate sensitive measurement instruments from external noise, interference, and surges. Isolation transformers have several inherent limitations, and must be used together with other filtering and surge protection devices. The first problem is voltage rating, it's difficult to find a mains-voltage isolation transformer rated beyond a few kilovolts. Secondly, a transformer offers strong protection in steady-state DC and low-frequency 50/60 Hz AC faults, but only limited protection from differential-mode transients and surges. If an electrical surge has significant energy that happens to overlap with the transformer's working frequency (for a switched-mode power supply, this is around several kilohertz), the surge can partially bypass the transformer and enter supposedly-isolated sensitive equipment. Parasitic capacitance is another problem. A capacitor is formed whenever two conductors are separated by an insulator, and the insulated windings inside transformers are no exception. At 100 MHz, the impedance of even a tiny 20 pF capacitance is 79.5 $j\Omega$. As a result, even though the DC impedance across a transformer is several megaohms, but it quickly deteriorates at high-frequency, allowing noise and interference to bypass the transformer and getting into sensitive

measurement instruments. Worse, the primary and secondary sides of the transformer can radiate strong electromagnetic interference, since a dipole antenna is formed by two metal plates at different electric potentials. The radiation is suppressed by bridging the transformer with capacitors, forcing the electric potential to be the same at both sides at high frequency. The drawback is a further increase of capacitance, and a possible reduction of the isolation voltage rating, since capacitors are often the weakest part of the barrier.

Thus, there are exotic situations where an electrical connection must be avoided at all costs regardless of its efficiency, when safety or electromagnetic interference problems are critical. Power over Fiber (PoF) technology has been developed to address these needs. Using lasers, photovoltaic cells, and an optical fiber in between, the isolated load can be placed at a long distance away, allowing high voltage rating and extremely low parasitic capacitance. One example is high-voltage isolation at utility-grid scale, when the voltage can be 10 kV or higher. Electronic Design magazine reported an early 2006 product, with the lasers in the transmitter consume about 48 watts of power, in order to deliver about 720 milliwatts at the receiver - an efficiency of 1.5%. More recently, Avago (now Broadcom) also commercialized this technology, with receivers available for sale at $710. "With 1.5 W of laser light incident [...] up to 120 mA of current can be extracted at an operating voltage of 5.0 V and a total power delivery of 600 mW." Typical applications include "high voltage current sensors and transducers", "E-field and H-field probes", and "MRI/RF imaging coils and patient monitoring equipment".

#2652: Proxy Variable

July 29, 2022
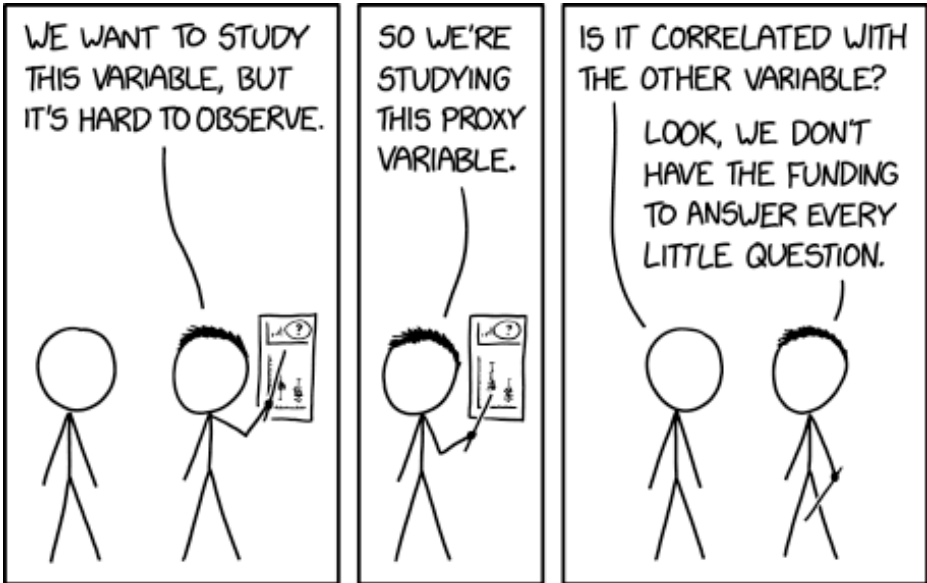
Our work has produced great answers. Now someone just needs to figure out which questions they go with.

Explanation

In this comic, Hairy is discussing use of a proxy variable with Cueball. In statistics, a proxy variable is used as a stand-in for one or more other variables that are difficult to measure. In order to be useful as such, proxy variables must be correlated with what they are intended to represent. For example, a drug might aim to reduce deaths from a slow-acting disease. But testing if it reduces deaths might take many years, so researchers might test for a proxy outcome instead, like whether the drug appears to mitigate loss of bone density or cell-damage. Physicians use blood pressure as one of many proxies for cardiovascular health.

Hairy is dismissing the question of whether they are studying the right variable as too expensive to answer. This is deeply ironic and thus satirical, because good experiment design requires sufficient attention to the robustness of all the involved parts of an experiment, even if the expense may be prohibitive. This comic might be referring to the recent discovery of nearly two decades of allegedly fraudulent Alzheimer's disease research supporting a mistaken proxy hypothesis.

Choosing the wrong proxy variable might make the research misleading, irrelevant, or as the title text suggests, answer the wrong question. Separating correlation from causation is necessary when interpreting proxy variable results to make sure the question they answer is known. Mere correlation instead of authentic

causation yields weaker results. Exploratory causal analysis can assist with finding useful proxy variables, but is difficult for the layperson to interpret and can be misleading, because even if performed correctly, a combinatorial explosion of possible proxy variables can make traditional statistical significance analysis fail, requiring F-scores or similar measures. The history of pharmaceutical research is largely a graveyard of failed proxy hypotheses; that is one of the reasons for experiment registration regulations.

The title text's notion of having an answer without knowing the actual question could also be be a reference to the classic comedy science fiction novel The Hitchhiker's Guide to the Galaxy, where in one scene Earth turns out to be a supercomputer built for the purpose of figuring out the question for the answer "42."

Examples of noteworthy proxy variables[edit]

- Loss of bone density or damage to cells for toxicity
- Blood pressure for cardiovascular health
- Amyloid markers for Alzheimer's disease
- Local temperature for global warming severity
- GDP growth for development (demolishing a hospital adds to GDP but subtracts from development)
- Money supply size for price inflation (see e.g. the paradox of thrift)
- Carbonic anhydrase expression for carbon sequestration
- Asphalt production for carbon sequestration

- Proportion renewable energy for carbon reduction (see Jevons paradox)
- Dialytic desalination for carbon sequestration
- Bacillus thuringiensis israelensis application for mosquito abatement
- Indoor carbon dioxide levels for air quality and ventilation

#2653: Omnitaur

August 01, 2022
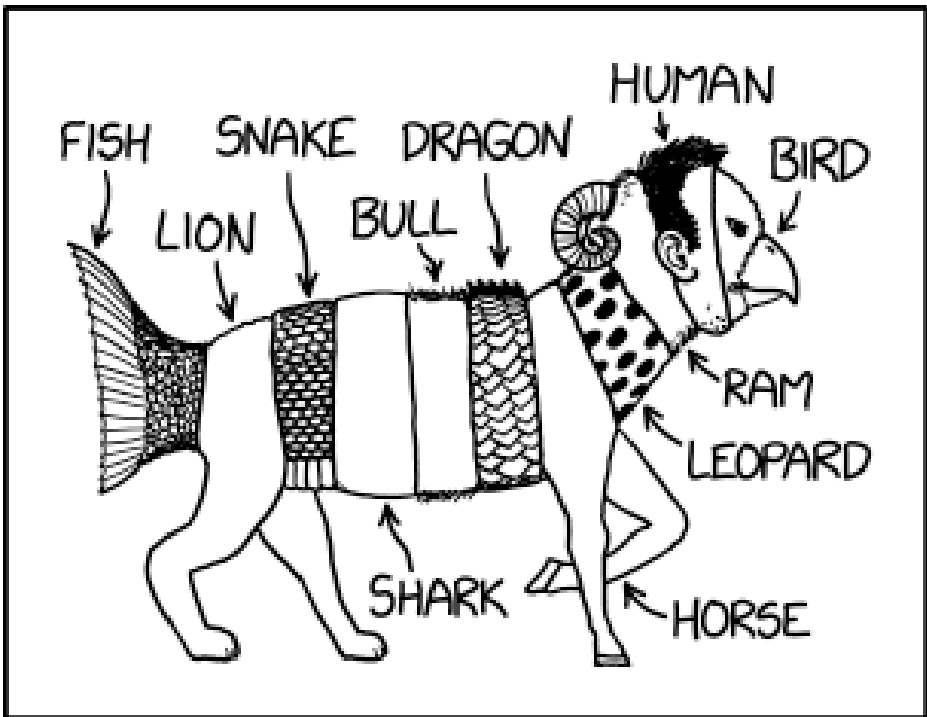
THE OMNITAUR

"My parents were both omnitaurs, which is how I got interested in recombination," said the normal human.

Explanation

Omnitaur is an anagram of minotaur, a mythical creature that was part man, part bull. "Omni-" is a prefix that means "all" that is, for instance, known from the word omnivore, meaning 'all eating' as compared to carnivore or herbivore — only eating meat or plant respectively. Given the combination of animals used to create the omnitaur, it could be expected that it was also an omnivore. The "-taur" part often means "bull," but it also appears in "centaur" via Latin from Greek kentauros (the name for a Thessalonian tribe of expert horsemen), meaning a different mythical creature which has the upper body of a human and the lower body and legs of a horse. So "-taur" could here be used to mean any creature made up of parts of different animals. An "omnitaur" would suggest that it would encompass all real and mythical creatures, or perhaps some random assortment of such. In this instance, it appears to be a hybrid, or genetic chimera, combined from eleven different creatures: fish, lion, snake, shark, bull, dragon (a mythical and often chimeric creature in its own right), horse, leopard, ram (male sheep), human and bird.

Chimerism is not uncommon at the genetic level; for example, humans have about 145 genes (out of around 30,000) originating from bacteria, other single-celled organisms, and viruses. Mitochondria, the powerhouses of the cell, were originally chimeric bacterial symbionts. But chimeras of larger organisms are rare, usually involving fraternal twins whose zygotes, blastocysts, or

embryos combined, as in conjoined twins, but resulting in less distinct phenotypical expression. Artificial human chimeras with viruses, mice, pigs, and monkeys have been the subject of ethics controversies in recent years. Interspecies blastocyst complementation, used to create human chimera organs and cell lines in other animals, is usually limited to combining two organisms into one whose offspring are not hybridized if they are even viable, and usually without human germlines or reproductive organs (or human central nervous systems, assuaging a major ethical concern).

The title text is a comment by a human whose parents were both omnitaurs. It would be funny that such parents would not produce offspring that were also omnitaurs. It suggests that this may be the result of genetic recombination, which is the exchange of genetic material between different organisms, most often two parents, leading to offspring with combinations of traits that differ from those found in either parent. In this case, they inherited only the human elements of each parent, apparently sufficient to develop into a whole human with no missing or chimeric elements. Both omnitaur parents likely had human germlines and compatible reproductive organs. Since the example depicted seems to be only 1/11 human, the odds of two parents as mentioned in the title text having fully human offspring would simplistically appear to be (1/11)11, or one chance in 285 billion. In reality, each physical part could not be the result of an equal recombinant genetic contribution, because the eleven animal chromosomes

vary widely in number and size. Moreover, chimeras composed of multiple animals do not have chimeric children, because even with multiple sets of reproductive organs, the germlines are not combined.[actual citation needed]

Chimeras in folklore[edit]

In addition to the minotaur and centaur, many other potential inspirations can be found in mythology, like the manticore, with a body of a lion and human face; a griffin, with a lion's body and a eagle's head; a mermaid, with a lower body of a fish and upper body of a human; a hippocampus, with the upper body of a horse and a lower body of a fish; a qilin, with a body that resembles both a horse and a dragon; or the mythological chimera, for which the genetic chimera is named, which has lion, snake, and goat body parts. Ultimately, there are lots of hybrid creatures in mythology with phenotypes combined from multiple animals. Usually, genetic hybridization produces much more smoothly blended phenotypes instead of dividing the body into large distinctly chimeric regions, although mosaicism of fur, skin or eyes can produce notable differences of hue or shade.

In C. S. Lewis' The Chronicles of Narnia, the centaurs are described as eating two meals — a huge roast meal "to satisfy the man stomach," and a meal of grass, "to satisfy the horse stomach," making it take quite some time for them to eat every morning. Since the omnitaur also has herbivore, carnivore, and omnivore parts, this could further support the supposition that it is an omnivore, and it may similarly need multiple stomachs for these multiple appetites. It is unclear how compatible the various diets of its components would be (not least because 'fish,' 'snake' and

'bird' are quite unspecific, and it's hard to know what a dragon would eat) but it would likely need several meals, taking even longer to eat than the centaur (plus the bird beak may slow the process down quite a bit). In any case, a chimera of both warm- and cold-blooded organisms seems unlikely to be viable,[citation needed] even at the organ level, let alone with combined surface phenotypes.

Dragons in Chinese folklore are often chimeras, described for example as having, "the head of a camel, the horns of a stag, the eyes of a demon, the ears of a cow, the neck of a snake, the belly of a clam, the scales of a carp, the claws of an eagle and the paws of a tiger." The Chimera monster in Dungeons and Dragons is a "vile combination of goat, lion, and dragon, and features the heads of all three," with similar depictions being common across fantasy media. The Aztec god Quetzalcoatl ("the feathered serpent") inspired the Discworld god/demon Quezovercoatl ("the feathered boa") ...being an analogue and mish-mash of various South American cultural and wildlife totems and described more fully as "as half-man, half-chicken, half-jaguar, half-serpent, half-scorpion and half-mad (a total of three homicidal maniacs)" with the small disadvantage of manifesting as only six inches high and being stepped on.

While chimeras occur in fantasy fiction, they also occur in science fiction, for example as cyborgs.[citation needed] The The Restaurant at the End of the Universe, the sequel to Douglas Adams' The Hitchhiker's Guide to the Galaxy, had a large fat meaty bovine dairy quadruped "with large watery eyes, small horns and what might almost have been an ingratiating smile on its lips." This "Ameglian Major Cow" seemingly had the mind and vocal tract of a human, so it could articulate how much it wanted

to be eaten.

The omni- prefix was later used in 2738: Omniknot and 3060: Omniroll.

#2654: Chemtrails

August 03, 2022
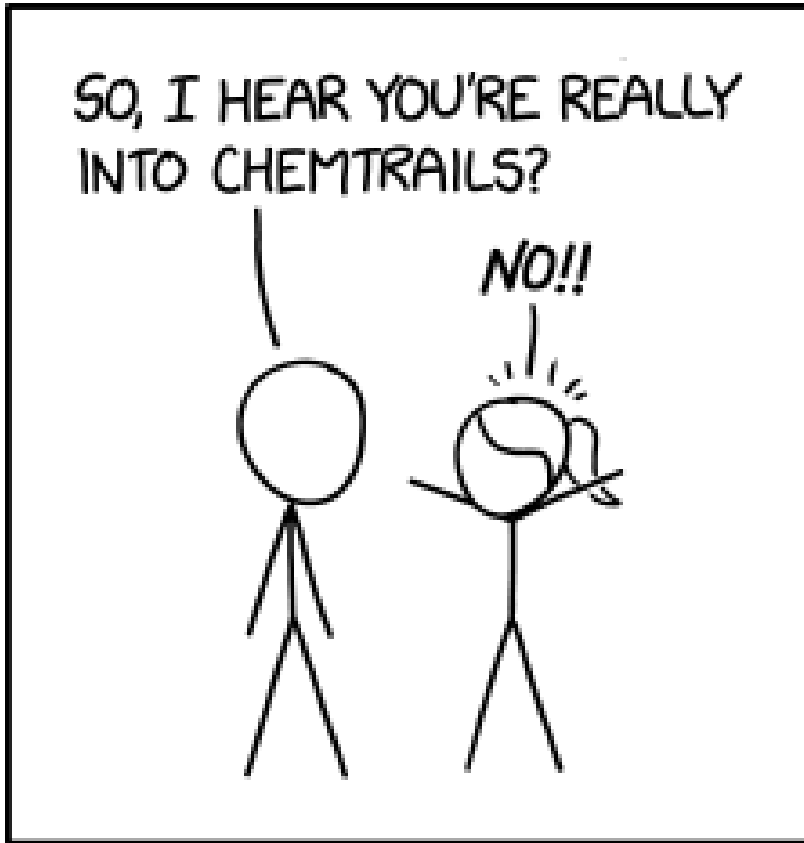
HOW TO ANNOY ENTOMOLOGISTS WHO STUDY ANT NAVIGATION

Ants have reverse chemtrails--regular citizens spraying chemicals everywhere they go to control the government.

Explanation

This is another comic on How to annoy people. Here Cueball annoys Ponytail, an entomologist who studies ant navigation, by telling her "So, I hear you're really into chemtrails?"

Two similar comics have been released, 2036: Edgelord and 2744: Fanservice, with the same settings but different text, both with White Hat being annoyed.

Entomologists study insects. Ants are social insects that leave chemical trails between locations such as newly discovered food sources and the nest. These chemical trails can guide other ants in their colony to the food, for example. Biologists call such signaling chemicals pheromones. This comic uses the word chemtrail as a shortening of chemical trail. Cueball is intentionally conflating ant chemical trails with chemtrails, the subject of a fallacious conspiracy theory that the government controls the population by spraying toxic or mind-/body-transformative chemicals from high altitude aircraft.

That conspiracy theory may be partly based on the practice of cloud seeding, which uses chemical flares containing silver nitrate to attempt to increase precipitation . Despite occasional conflation, chemtrails are distinct from "contrails," short for "condensation trails," which are cloud-like lines in the sky created by airplane engines or airfoils. There is very little evidence

that sophisticated mind control posited by chemtrail conspiracists is possible, even after extensive research.

Ponytail is an entomologist, studying chemically mediated cooperative ant navigation. Cueball knows she will be annoyed when he tells her, "So, I hear you're really into chemtrails?" Indeed, he gets the reaction he hoped for when she objects strongly and rejects this with a loud, "No!!" The choice of terminology is often a sore spot for those who study a particular field in depth. Randall writes in the caption that such misuse is how to annoy people like Ponytail.

The title text humorously notes that ants' "chemtrails" have the opposite effect from the chemtrails of the conspiracy theory.

Ants are a recurring theme, as are those who study them. See for instance 638: The Search which specifically deals with ants' pheromone trails or 1610: Fire Ants. Chemtrails were also the subject of 966: Jet Fuel, 1677: Contrails, and were mentioned in 1803: Location Reviews.

#2655: Asking Scientists Questions

August 05, 2022
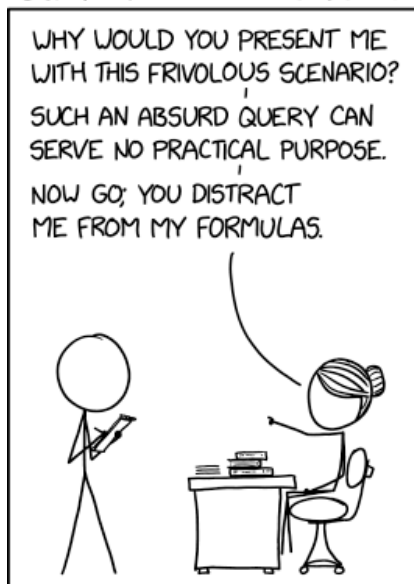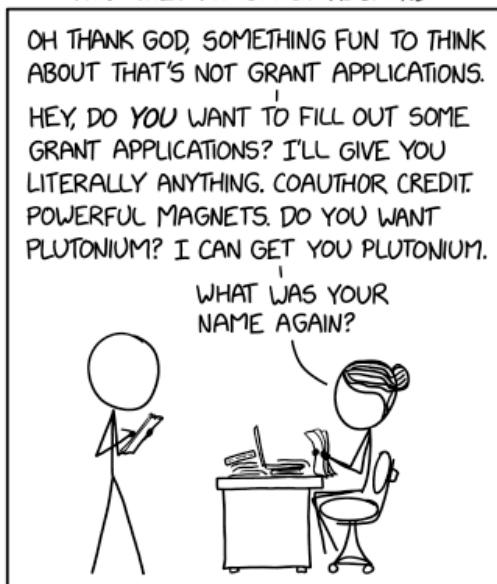
'Does the substance feel weird to the touch?' is equally likely to get the answers 'Don't be ridiculous, you would never put your hand near a sample. We have safety protocols.' and 'Yeah, and it tastes AWFUL.'

Explanation

Answering the questions in Randall's what if? blog and his books What If? and What If? 2 requires a wide variety of scientific expertise, much of which he is unfamiliar with. To make up for this deficiency, Randall (here represented by Cueball) asks other scientists for help, in this comic represented by Hairbun.

Normal people (not from the scientific community) have certain expectations about scientists, as they would any group of people.[citation needed] In the case of scientists, they are often expected to be overly serious, "measuring the marigolds" rather than enjoying the simpler or more subjective things in life. This is reflected in the first panel, where Hairbun gets annoyed by Cueball's "frivolous scenario" and wants to work on formulas instead. This is the scenario one would have expected from the standard assumptions regarding scientists.

In reality, scientists are just like regular people in most respects (as has been represented before in xkcd) and this is why Randall, in reality, is more likely to experience something like what is shown in the second panel. Here Hairbun is quite pleased to get "something fun to think about" as part of their work, instead of filling out her grant applications.

Grants are donations of money from private or government organizations specifically aimed to fund

scientific experiments and projects; in many fields, they are the most common source of funding, and the vast majority of scientists not directly employed by private industry rely on grants to support their work. These organizations require applicants to provide detailed information on the goal of the project, the methodology, the expected results, the specific uses to which the money will be put, and more. Applying for a grant is thus a lengthy, painstaking process that more often than not results in disappointment since most granting agencies have only enough money to approve a small percentage of applications. It also has little to do directly with the actual science the scientists want to perform. Thus most scientists find it a necessary but time-consuming and unpleasant part of their job, and the one here expresses relief at taking a break from this part of their work.

Hairbun then asks if Cueball would like to fill out grant applications, trying to bribe him with coauthor credit, powerful magnets, and plutonium. Co-authorship on scientific papers helps scientists advance in the "publish or perish" world of academic careers; such co-authorship might be above-board, if Cueball contributed scientific ideas while helping write grant applications, or it might not. Plutonium is used in making atomic bombs and is thus a tightly controlled substance, as well as being highly toxic due to both its radioactivity and its heavy metal poison effects. The scientist is so relieved to have found someone who might take over filling out grant applications that they are willing to give them access to such a dangerous material without even knowing their

name. (Hairbun previously offered an entire moon in 2204: Ksp 2, for delaying the launch of Kerbal Space Program 2.)

The title text notes that not all responses were complaints about grant applications, noting two kinds of answers to the question "Does the substance feel weird to the touch?" which Randall claims are equally common. The first is the sort of response you would expect from a stereotypical scientist, just noting safety procedures that are common with such a substance and how they impede attempts to determine how weird a substance feels. The second is "Yeah, and it tastes AWFUL," implying that the scientist in question has not only touched the weird substance, but also tasted it. It could have been carelessness of some kind, perhaps having touched their mouth after handling a sample, but it might have been from deliberately licking it or even putting it in their mouth. Whatever the reason they tasted it, they are enthusiastically volunteering this elaboration without any actual prompting.

Eating a bizarre substance is likely a bad idea,[citation needed] as it could be poisonous. Less toxic minerals such as halite are sometimes evaluated based on taste as an informal test of their composition; nearly every mineral of low toxicity (and some otherwise) has been tasted for science. However, this is self-evidently a bad idea if you're not sure whether a mineral is a non-toxic one or a similar-looking toxic mineral; mineral taste-tests should only be performed by experts who know they're not eating arsenic or stibnite.

#2656: Scientific Field Prefixes

August 08, 2022

NUMBER OF SEARCH RESULTS ON GOOGLE SCHOLAR

	PHYSICS	CHEMISTRY	BIOLOGY	ENGINEERING	PSYCHOLOGY	THEOLOGY	DENTISTRY
THEORETICAL	3,990,000	445,000	553,000	2460	15,500	726	41
QUANTUM	478,000	740,000	7,620	21,100	699	447	NONE
HIGH-ENERGY	844,000	9,600	3	119	1	NONE	NONE
COMPUTATIONAL	510,000	599,000	2,910,000	67,400	4,620	40	11
MARINE	3,920	136,000	945,000	108,000	35	6	1
ASTRO-	2,010,000	20,600	226,000	430	64	580	NONE

POTENTIAL RESEARCH OPPORTUNITIES: QUANTUM DENTISTRY, HIGH-ENERGY DENTISTRY, ASTRODENTISTRY, AND HIGH-ENERGY THEOLOGY

Massage: Theoretical (10), Quantum (6), High-energy (2), Computational (1), Marine (1), Astro- (None)

Explanation

Google Scholar is a search engine for academic publications, and Randall has been having fun with it.

Randall searches for various terms that are composed of some common prefixes and common suffixes, but not always commonly associated with each other in each possible combination, and tabulates the results. See this table with numbers for easy overview.

This reveals some very commonly used full terms like "Theoretical Physics", the most discovered, which represents almost four million hits compared to the next highest, "Computational Biology", with almost 3 million hits and Astrophysics with 2 million hits. Ducking just below 1 million hits is fourth placing Marine Biology. Of the 42 possible fields just 14 have more than 100,000 hits, and only four more have over 10,000.

But there are also some that have much lower numbers, eight with fewer than 10 hits in the table. "High-Energy Psychology" and "Marine Dentistry" have just one apparent occurrence each (equivalent to a Googlewhack), whilst there are no hits at all recorded for four of the initially combined terms. In total (with the title text) there are 48 fields, see a full list of scientific fields below.

An explanation for both existing and fictive scientific fields can be given below in the table with explanations.

In the caption to the table Randall list four potential research opportunities i.e. those with no hits in the table: Quantum Dentistry, High-Energy Dentistry, Astrodentistry and High-Energy Theology

He thus suggests that, because of the (apparent) lack of current studies in these specialized sub-fields, there may be unexplored potential for a study. This could be that the more "used" areas have far too much competition and be might already be "used up" for potentially useful discoveries. (This does not account for how much 'study space' might be available in a given box of research, even though Randall has previously hinted that anything "Astro"-related is potentially full of many things to study.)

Of course the real reason for no one studying these fields are that they make no sense. Dentistry is related to fixing peoples teeth. The quantum world has no effect on human teeth,[citation needed] and high-energy bombardment of a human's mouth may also be a bit dangerous (although x-rays and radiation treatment in the mouth could be seen as high energy). Astrodentistry is not really relevant if seeing this as something used on humans. Of course astronauts might need dentistry while in space, but it would be a stretch to call the study of dentistry in zero-G, "astrodentistry". "High-energy Theology" as a term, seems more likely to have been used...

In the title text Randall lists the figures for another 'major' field suffix, "Massage", and the numbers of its

prefixed forms. From this, we learn that Astromassage is another 'open' field that is currently unstudied, but none of the five others have more than 10. Probably the most surprising aspect of the title text is that there are hits for both quantum massage and high-energy massage.[citation needed]

Table with numbers[edit]

- Here the table is presented with only numbers, so it can be sorted.

Massage from the title text has been added.

List of Scientific fields[edit]

This is included for easy reading of the numbers:

- Theoretical Physics: 3,990,000
- Theoretical Chemistry: 445,000
- Theoretical Biology: 553,000
- Theoretical Engineering: 2,460
- Theoretical Psychology: 15,500
- Theoretical Theology: 726
- Theoretical Dentistry: 41
- Theoretical Massage: 10
- Quantum Physics: 478,000
- Quantum Chemistry: 740,000
- Quantum Biology: 7,620
- Quantum Engineering: 21,100

- Quantum Psychology: 699

- Quantum Theology: 447

- Quantum Dentistry: None

- Quantum Massage: 6

5 of these are objections to pseudoscientific healing nonsense. The last is from a Dutch medical text in which one sentence ends with "quantum" and the next begins with "massage", published in 1895 and having nothing to do with quantum mechanics.

- High-Energy Physics: 844,000

- High-Energy Chemistry: 9,600

- High-Energy Biology: 3

Two of these are for the same conference proceedings about use of accelerators in biological research. The third is from an article which mentions a list of research areas: "extensive programs in chemistry, physics (other than high energy), biology".

- High-Energy Engineering: 119

- High-Energy Psychology: 1

Job ad from October 31st, 2001, asking for "high energy psychology, speech pathology or special education majors to work with our mildly autistic son"

- High-Energy Theology: None

- High-Energy Dentistry: None

- High-Energy Massage: 2

- Computational Physics: 510,000

- Computational Chemistry: 599,000
- Computational Biology: 2,910,000
- Computational Engineering: 67,400
- Computational Psychology: 4,620
- Computational Theology: 40
- Computational Dentistry: 11
- Computational Massage: 1

This is an article about modular wearable electronic devices, in the form of clothing, which provide massage.

- Marine Physics: 3,920
- Marine Chemistry: 136,000
- Marine Biology: 945,000
- Marine Engineering: 108,000
- Marine Psychology: 35
- Marine Theology: 6
- Marine Dentistry: 1

The paper mentions the application of something in "Transportation, Marine, Dentistry, Electronics" and other fields

- Marine Massage: 1

Article in "Professional Beauty" of 2021, mentioning "An exceptional massage technique with the professional-only Oligo-Marine Massage Cream includes smoothing, relaxing and stretching movements for total relaxation and optimal skin"

- Astrophysics: 2,010,000
- Astrochemistry: 20,600
- Astrobiology: 226,000
- Astroengineering: 430
- Astropsychology: 64
- Astrotheology: 580
- Astrodentistry: None
- Astromassage: None

#2657: Complex Vowels

August 10, 2022
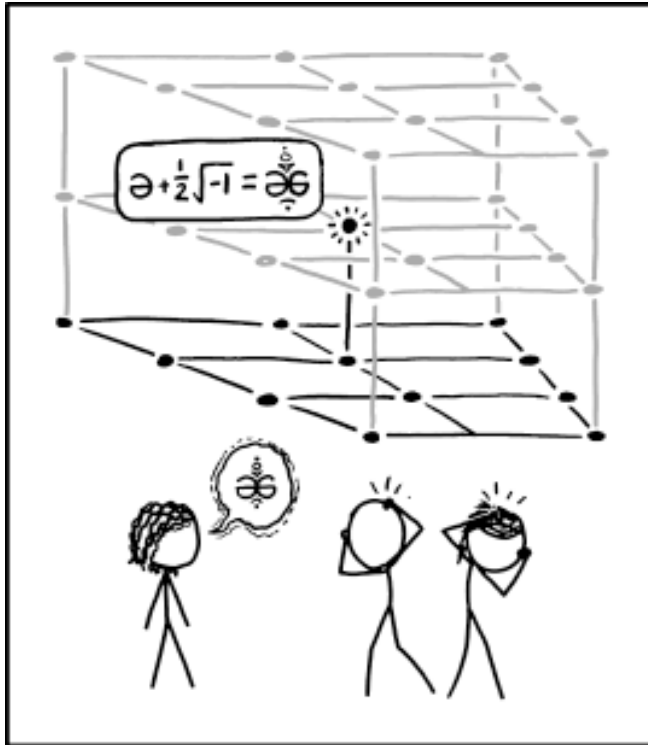
LINGUISTICS TIP:

EXTEND THE IPA VOWEL PLANE ALONG THE IMAGINARY AXIS TO PRODUCE THE *COMPLEX VOWELS,* CURSED SOUNDS WHICH THE HUMAN MIND CANNOT COMPREHEND.

Pronouncing [sscchhwwaa] is easy; you just say it like the 'x' in 'fire'.

Explanation

This is another one of Randall's Tips, this time a Linguistics Tip. The curly-haired linguist, Gretchen McCulloch, manages to produce a cursed sound using complex vowels, which cannot be comprehended by normal humans like Cueball and Megan, who both seem to get a headache from listening to the sound. The sound she makes was produced by extending the IPA vowel plane along an imaginary axis to form the complex vowels.

In phonetics based on the International Phonetic Alphabet (IPA), the space of vocal tract articulators determining vowels is represented as three dimensional, from the position of the tongue and lips. The vertical axis represents vowel height or closedness (i.e., how close or far the tongue is from the top of the mouth), and the horizontal axis represents front-to-back place (i.e., how close or far the top of the tongue is from the teeth.) The position of the tongue, along with the frequency of the vocal cords vibrating in the larynx from air being exhaled by the diaphragm, are the primary determinants of the fundamental and second formant frequencies of vowel sounds. A third dimension of vowel sounds is the "roundedness" of the lips, represented on the IPA vowel chart to the right by pairs of vowel phoneme glyphs. Other higher-dimensional vowel representations include diphthongs, which are simply two different sequential vowels slurred together; diphones, which represent the last half of one phoneme followed by the first half of the

next; vowel shift mappings delineating different accents and long-term evolution of voiced phone sounds; and cepstral representations such as mel-frequency cepstral coefficients.

Randall suggests increasing the range of vowel sounds available by using complex notation to indicate an additional dimension with an "imaginary" axis. In mathematics, complex numbers are numbers including both real numbers and imaginary numbers. A complex number can be expressed as, "a + bi," where a and b are real numbers, but the latter imaginary part is combined with 'i,' the square root of negative one, as depicted in the central expression in the comic by √-1 indicating a further dimension of coordinates. When expanding the one-dimensional number line with an imaginary axis, it becomes two-dimensional with the "bi" component orthogonal to the original "real" number line. Linguists never use the complex plane to represent vowel roundedness or any other higher-dimensional features of phonemes, although the properties of complex numbers could conceivably support representing physiological features of the vocal tract, such as prior position of the articulators.[citation needed]

This comic conflates complex numbers in mathematics with "complex vowels" in linguistics. Such complex vowels are implied to create sounds which cannot be properly processed by the human brain and represents one with a heavily modified "schwa" ∂ phoneme, mirrored vertically and surrounded by multiple diacritics akin to the Zalgo text meme. The sound of this

supposedly alien vowel has Cueball and Megan clutching their heads. Overall, Randall's complex vowels bear similarity to the cliché of "black speech" in Lovecraftian horror, a language created by alien beings with different vocal patterns than humans.

In linguistics, 'ə' is the schwa symbol, referred to in the title text and the depiction of complex phonemes, the most common vowel sound in English polysyllabic words (the 'a' in "comma" or the second 'e' in "letter.") Production of the schwa sound takes place with the tongue, jaw, and lips all in a relaxed, central position, and is often entirely optional in many if not most dialects of English. The pronunciation of "[ṡṡċċḣḣẇẇȧȧ]" in the title text is said to sound like the x in the word fire. In fact, there is no x in fire.[citation needed] This is perhaps in line with the idea that complex sounds are incomprehensible to most humans, and likely also impossible to pronounce by anyone other than experts such as Gretchen. Another example of weird diacritics is in 2619: Crêpe, and with Zalgo text in 1647: Diacritics. The use of typography to create psychological stress is explored in 859: (.

#2658: Coffee Cup Holes

August 12, 2022
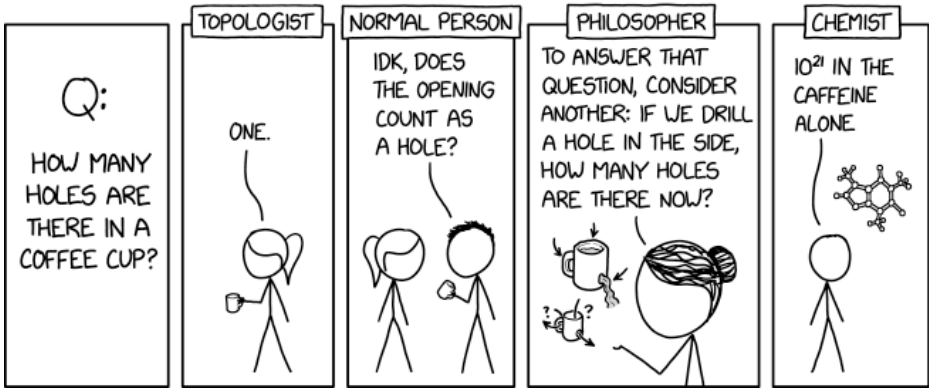
Theoretical physicist: At the Planck length, uncountably many.

Explanation

This comic depicts people in different fields of study answering the question, "How many holes are there in a coffee cup?" and also compares this to what a normal person would say.

This question has different interpretations, entirely dependent upon the definition of a hole. The type of coffee cup shown in the comic is with a handle (like a mug), but Randall calls it a cup and there are also cups with handles on the Wikipedia page for coffee cups. Most people would recognize that there is a hole through the handle.

The comic explores the answer to the question through several peoples' avenues of thought, and is funny because of the ambiguity:

Topologist[edit]

Ponytail, a topologist, states the coffee cup belongs in the genus of one hole. From the topologist's point of view, the coffee cup definitely has one hole, which corresponds to the opening created by the cup handle. A cup without a handle would have zero holes, as it is equivalent to a dinner plate, just an indentation in the surface. See 2625: Field Topology for more information about topology.

The panel as a whole references an academic joke wherein topologists can't tell the difference between a coffee cup with a handle and a doughnut since they're homeomorphic to each other

— meaning they have the same genus (i.e one hole).

Normal person[edit]

Hairy, representing a normal person, is not sure (the acronym "IDK" stands for "I don't know") and asks for clarification about whether the opening at the top counts as a hole. This shows flaws in the question, which suffers from the mathematically imprecise, ambiguous common usage of the word "hole." Topologists would refer to the opening as a concavity, not a hole, and while they consider such geometrical properties generally outside their field, most practical applications of topology do involve geometric components. By contrast, in everyday usage many concavities are called holes, such as a hole dug into dirt with a shovel. Hairy would say one for the handle, and two if the opening counts as a hole, which he is not certain the one asking the question thinks.

Philosopher[edit]

Hairbun, a philosopher, answers the question with an elucidating counter-question, considering a hypothetical scenario. One might expect that drilling a new hole would also increase the number of holes by one. However, as illustrated, some people would consider that the new arrangement has three holes (in addition to the handle, there is a hole at the top where coffee can be poured in, and one at the bottom where it can run out), while others would consider it to have only two (the new hole forming a continuous hole with the original opening at the top, through which coffee can run). Some might in fact say that the coffee cup now has one hole because it is leaky, disregarding the handle topology at this point. In this way she requires her interlocutor to confront the ambiguities and consider what they mean by the word 'hole' in different contexts. An interesting point about Hairbun's response

is that she doesn't actually answer the question, a trope often found in philosophical replies.

Chemist[edit]

Cueball, a chemist, looks at the coffee in the cup on a molecular level. He envisions a ball-and-stick model of the caffeine molecules in the coffee, and estimates a total number of holes of all the coffee molecules. He comes up with a truly massive number: 1,000,000,000,000,000,000,000 (1021 or 1 sextillion) "in the caffeine alone." One molecule of caffeine has two rings of bonds with holes in them, multiplied by 500 quintillion molecules, or 0.00083 moles. As the molecular mass of caffeine is about 194 grams per mole, Randall must think that the mass of caffeine in a typical cup of coffee is 161 milligrams. The coffee could have other holes, depending on the type of coffee; for example, espresso contains significant amounts of niacin and riboflavin, which have one and three rings in their chemical structure, respectively.

This estimation depends on taking the ball-and-stick model of molecules somewhat literally. However, real molecular bonds are not solid sticks, but shared electron clouds between atoms. The "holes" in the middle of a molecule's rings are not completely empty but instead merely have lower electron probability density through the middle than other parts of the bonds. So the point-cloud duality of electron orbitals and bonds might not satisfy a topologist's, normal person's, or philosopher's criteria for a connected substrate in which holes may be formed.

Theoretical physicist[edit]

In the title text, a theoretical physicist looks even deeper, at the

subatomic scale of Planck units. Since fundamental particle interaction is governed by fundamental forces and collision (per the Pauli exclusion principle) instead of tensile or ductile solid connectedness, the theoretical physicist posits that any definition providing for a single hole would also describe a number of holes akin to the factorial of the number of particles in the universe, or at least within the cup's light cone, which is a number impractical to accurately count, but not uncountable in a mathematical sense.

Practical considerations[edit]

The main joke is that the number of holes depends on both the scale and perspective from which you are looking at the world. From a topological standpoint, when someone digs into the ground it should go all the way through (down and up again another place) before it is considered a hole, since a hole is something that some other thing should be able to pass through. But from a common usage perspective, if people dig in the ground the result is called a hole, because functionally it creates a discontinuity in to which, for example, things can be placed or fall. Similarly, the opening in a coffee cup without a handle or a bottle of beer is called a hole, even though they are topologically equivalent to a dinner plate, which normal people would never say had a hole.

A cavity in a surface could also be considered a physical barrier, preventing movement along the surface in certain scenarios (e.g. a sinkhole opening up in the middle of a road) even though it may be topologically 'flat' in the most general way, and so is very open to context, and such a hole might be considered more a 'thing' than the surface that has been removed to create it. And a concavity in a vessel that can hold liquid (or a drilled hole which

removes that ability) is of a different nature from the holes in the molecules that are part of the liquid therein. And such holes very different from the string-theoretical holes at the Planck scale, which don't necessarily involve barriers, containment, or any other aspects of topological connectivity. This conceptual ambiguity of what a hole is or means is demonstrated by the fictional portable hole, which obeys and defies a normal person's preconceptions of a hole.

The topological discussion here regarding cups and doughnuts is related to the question of how many holes there are in a human, which is excellently answered in Vsauce's video

How Many Holes Does a Human Have?. This also takes a good look at the topological difference between a paper cup and a mug with handle, and how one could be morphed into a plate and the other into a doughnut.

#2659: Unreliable Connection

August 15, 2022
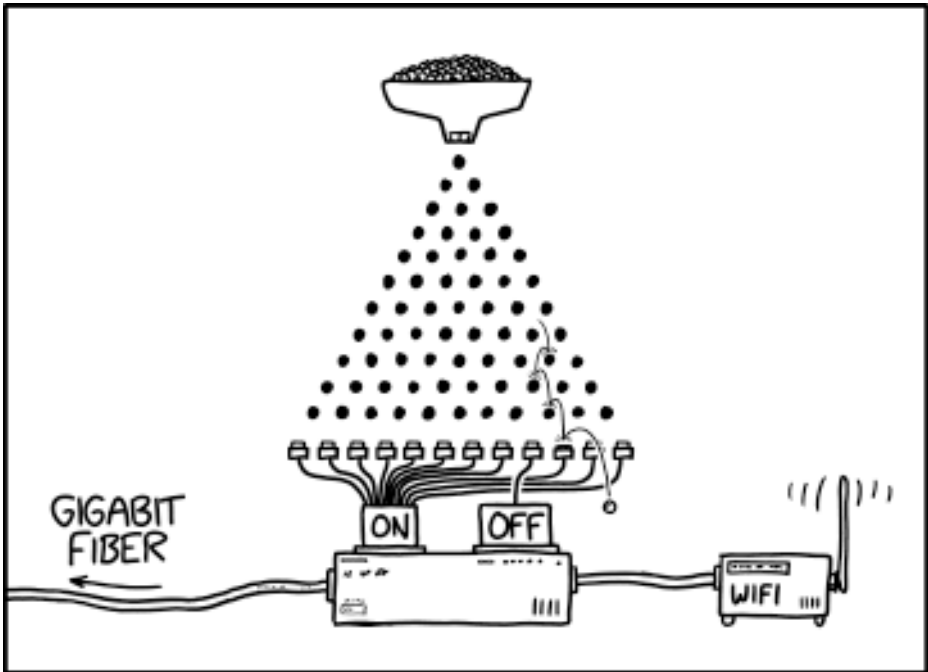
MY NEW VACATION SPOT HAS VERY FAST INTERNET THAT TURNS OFF RANDOMLY EVERY NOW AND THEN, JUST SO YOU CAN TELL PEOPLE YOU'LL BE STAYING SOMEWHERE WITHOUT A RELIABLE CONNECTION.

NEGATIVE REVIEWS MENTION: Unreliable internet.
POSITIVE REVIEWS MENTION: Unreliable internet.

Explanation

In today's world, the Internet, pervasive mobile technology and the COVID pandemic have all caused an implicit expectation for many people to be available all hours of the day, whether for work or social communications, even when on vacation. In this comic, Randall addresses the issue with a deliberately suboptimal internet device that drops Internet connectivity intermittently and at unpredictable intervals, thereby causing activities that require a constant, uninterrupted connection to be unusable. The device appears to be an internet modem connected to an automated version of a Galton board or Jin Akiyama's mathematical pachinko machine with a series of twelve switches at the bottom to be pressed by falling balls, eleven of which are linked to a the label "on" and one linked to a second label "off," both such sets of switches apparently controlling the connection. This solves the social problem of demands for the likes of synchronous teleconferencing, by causing asynchronous methods of communication to be relatively more reliable and efficient for personal use.

This is funny because such a device could likely much more easily be implemented in the firmware of the internet or WiFi modem or routers. (See 1785: Wifi for an explanation of firmware.) It's not clear whether the switches merely interrupt the connection momentarily or control power to the modem, which would involve a much longer booting sequence. The "unreliable"

connection provides an excuse to be unavailable for work or social calls, and thus free to enjoy one's vacation. However the device also allows the user to have a fast internet connection most of the time, enabling them to use it for leisure purposes, such as downloading movies for entertainment, or to connect with others on one's own terms. It thus retains most of the benefit of a good connection.

The probability of a ball hitting the "off" switch is 165/2048, or about 8% (assuming the machine is ordinary, and the space between switches is disregarded) because it's in the ninth position. We don't know the frequency with which new balls are dropped, so we can't estimate the frequency at which the device is likely to trigger Session Initiation Protocol, Transmission Control Protocol, or similar timeout conditions that would likely close synchronous VOIP, video conferencing, and e.g. VRChat connections. Even if such connections were to survive the induced service interruptions, the application layer call or teleconference quality would suffer during them. The device may cause interruptions rarely enough that the connection is usable for casual purposes, but the user can still reasonably claim that it's unreliable to get out of online obligations.

The title text reflects on today's increasingly always-connected world, where emphasis may be changing from finding rare vacation spots that have reliable internet, to now finding somewhere worthwhile to go that still doesn't have it. It could also be a comment on the mild paradox that a nominally unreliable internet

connection has advantages for those whose communication schedule, volume, or style preferences make synchronous teleconferencing less practical, desirable, or both. The reviews for the new vacation spot indicate that disconnections are found to be both desirable and undesirable, possibly even by the same person.
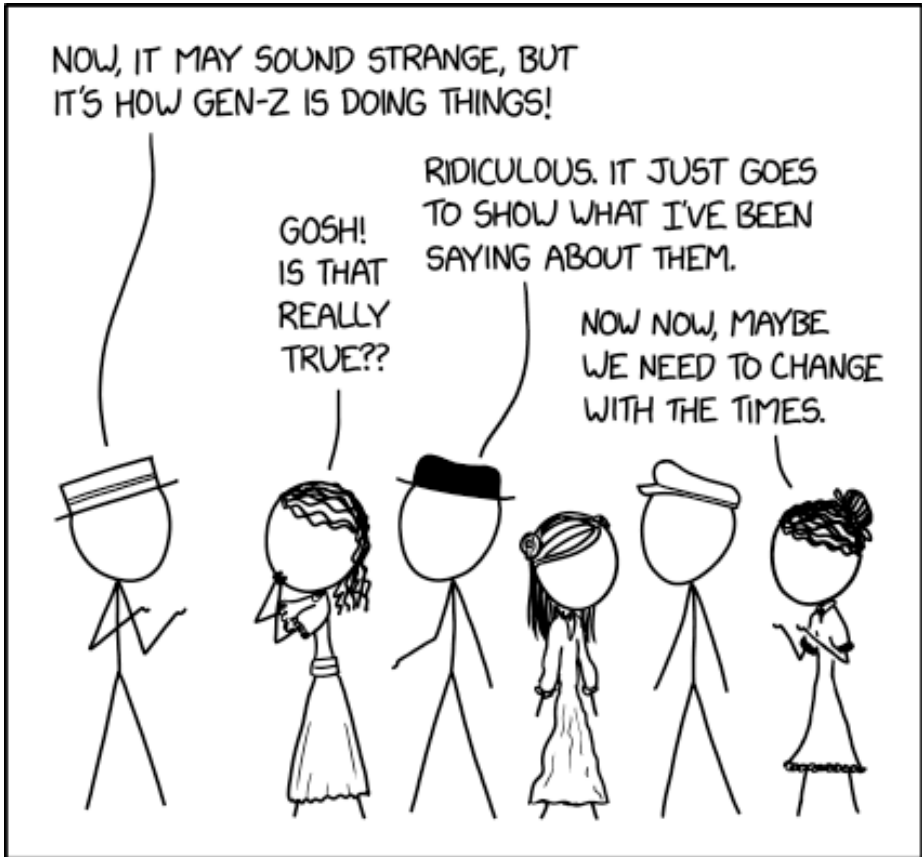
PEOPLE ASCRIBING QUALITIES TO "GEN Z" HAVE THE SAME ENERGY AS SMALL-TOWN SALESPEOPLE IN 1905 TALKING ABOUT WHAT THE LADIES IN PARIS ARE UP TO.

Curdled milk, of a peculiar kind, made after a Bulgarian recipe and called "yaghurt," is now a Parisian fad and is believed to be a remedy against growing old. A correspondent who has tried it, says he would prefer to

die young. **(1905, The Elk Falls Journal)**

Explanation

Older generations are often confused by the trends and norms of younger people, and this comic aims to contextualize this common situation by placing it in a historical perspective — featuring the usual cast of xkcd in historical garb. White Hat (wearing a white boater) has seemingly just finished introducing a topic of discussion to the rest of the group; he knows the rest of his group will find the topic weird, but is willing to defend Gen Z with the excuse "that's just how they do things." Black Hat is expressing a notion that sounds a lot like juvenoia, and is quick to make sweeping generalizations about the younger group. The other reactions depicted are representative of the broader spectrum of possible responses: either surprised interest or cautious acceptance. There is no evidence that White Boater is correct about how Gen-Z does things.

Neither knee-jerk rejection nor forward-looking sympathy are specifically praised by the main text of the comic, but the example highlighted in the title text seems to imply that Randall would like to emphasize openness to new things.

The title text quotes a newspaper from Elk Falls, Kansas, which on May 18, 1905, told of a "Parisian fad". The item was a shortened version of an account which also ran in many other newspapers. In this case, the "fad" is the introduction of yogurt (spelled "yaghurt" in this publication, probably because English spelling of the

word was not standardized yet and may have been influenced by the French spelling ("yaourt") and phonology). In the modern day, yogurt is enjoyed as a common food in most cultures, but in 1905 the concept was bizarre and repulsive to many readers. This shows that things which are dismissed as "strange" because of preconceived notions of a particular group (that curdled milk is necessarily bad) may, in fact, be perfectly acceptable once more context is obtained. It is also worth noting that yogurt was not invented in 1905, but had existed for centuries prior; despite this, the recent introduction to French culture is what prompted its recognition as a nascent "fad". This may be analogized to various fads and trends which Gen Z is embracing which may appear unfounded to members of older generations, but which nevertheless represent acceptance of ideas which did not originate with members of that generation. Randall may have chosen this particular version of the item in part because it omits some of the statements in the longer item, such as that consumption of yogurt could "prolong human life to what is its normal span - a century or so."

This is not the first comic to identify "modern" complaints or viewpoints as having been present throughout history in various forms (see comics 1227: The Pace of Modern Life and 1601: Isolation).

The humor in making generalizations about people born in specific time periods is also seen in 973: MTV Generation, 1962: Generations and 2249: I Love the 20s.

#2661: Age Milestone Privileges

August 19, 2022

AGE MILESTONES
AND ASSOCIATED PRIVILEGES

16 DRIVE
17 ATTEND R-RATED MOVIES ALONE
18 VOTE
21 BUY ALCOHOL
25 RENT A CAR
30 RUN FOR SENATE
32 RENT A SENATOR'S CAR
35 RUN FOR PRESIDENT
40 RENT A FLYING CAR
45 LEARN ABOUT THE GOD-EMPRESS
50 JOIN AARP
50 GET A SHINGLES VACCINE
52 CLICK TO SKIP CAPTCHAS
55 VOTE FOR GOD-EMPRESS
62 $80 NATIONAL PARKS LIFETIME PASS
65 ELIGIBLE FOR MEDICARE
67 COLLECT SOCIAL SECURITY
68 SEE "SKIP ADS" BUTTON ON LIVE TV
70 RUN FOR GOD-EMPRESS
75 RIDE ANY ANIMAL IN A NATIONAL PARK
80 ELIGIBLE FOR MEGACARE
85 CLICK TO TOGGLE WHETHER ANY AD IS POSITIVE OR NEGATIVE ABOUT THE PRODUCT
90 CLICK TO MAKE ANY MOVIE R-RATED
100 GET A LETTER FROM THE PRESIDENT
102 (35+67) COLLECT A PRESIDENTIAL PENSION
105 GET A BIRTHDAY CARD FROM THE GOD-EMPRESS
111 LEAVE YOUR OWN BIRTHDAY PARTY EARLY BY PUTTING ON A MAGIC RING
118 VOTE 100 TIMES
120 COLLECT THE PENSIONS OF ALL ELECTED OFFICIALS
125 DRINK ALCOHOL IN AN R-RATED MOVIE WHILE GETTING A SHINGLES VACCINE FROM THE PRESIDENT
128 AGE ROLLS OVER, BECOME A BABY AGAIN

If you reach 122, you get complete unrevertible editorial control over Jeanne Calment's Wikipedia article.

Explanation

This is a list of "age milestones" in the United States. As usual for Randall, he has added many fictional entries to supplement some real life ones. The real milestones are the ages at which Americans are generally allowed to do certain things for the first time. These are a mix of legal restrictions (such as the age for driving and voting), rules from private companies (such as movie theaters and car rental companies) and medical guidance (like the shingles vaccine).

In general, avoid exposure to any temperatures, pressures, particle energies, or states of matter that physicists think are neat.

Explanation

This is another one of Randall's Tips, this time a General Physics Safety Tip. This comic also serves to promote his new book as it states that this flow chart is taken from the What If? 2 book, and the shorter link to his promotion page is written in the comic: xkcd.com/whatif2. The what if? blog as well as both books gives answers to odd or strange science questions.

In general, there are very narrow ranges of temperature, pressure, and chemical makeup humans can survive in. Human physicists necessarily spend all their time in these conditions and think of them as ordinary. The physics of these ordinary conditions has already been thoroughly studied, which makes them now familiar and boring. Instead physicists get excited to study more extreme conditions, most of which would be quickly lethal to humans — anything from the event horizons of black holes to the vacuum of space, to volumes where charged particles traveling near the speed of light are forced to collide, and many, many things in between. Thus, extreme conditions are very dangerous for most organisms. Even for especially resilient organisms, such as tardigrades, there is a point past which they will stop being biology and start being physics, in which case their resilience will not save them. Thus if a physicist is excited about something, it likely exists in circumstances where your own existence — as well as other life — would meet an end. One (partial) exception is particle beams; people can stick their heads in particle beams and survive — but

not unscathed. Also, physicists used to be excited about (particles produced by) cosmic rays before they had powerful accelerators.

Clicking anywhere in the comic takes the user to the link. It has been a general thing for Randall to comment on the fact that he does not know how to make only part of an image into a link, which he also did recently in the header text.

#2663: Tetherball Configurations

August 24, 2022
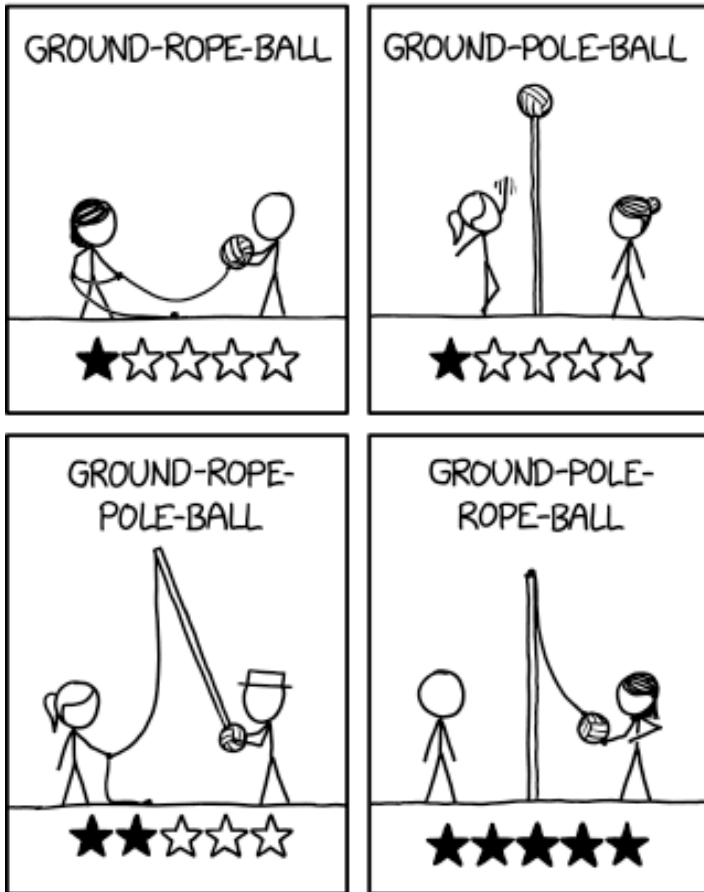
Ground-pole-ball-pole can be fun if you shake the first pole to get the second one whipping around dangerously, but the ball at the joint gets torn apart pretty fast.

Explanation

Tetherball is a game for two players with the objective to wind a rope completely around a pole. The rope is attached (tethered) to the pole on one end and to a ball on the other end. The players try to wind the rope in opposite directions and do so by hitting the ball at the rope's loose end with their hands or with paddles. Randall has the usual configuration last with five stars, preceded by several humorously inane configurations with fewer stars:

Ground-rope-ball receives only one star because there is no way to keep "score". Megan holds the rope while looking at Cueball holding the ball. What to do...

Ground-pole-ball receives only one star because there is no way for anything to happen. The pole is fixed in place, and the ball is fixed in place at the top. Ponytail can be seen waving her hand at the ball at the top of the pole, but it's too tall and she can't even reach it. Hairbun has just given up.

Ground-rope-pole-ball is slightly better than the previous configurations and therefore receives two stars instead of one. The players have some way to keep score by seeing which way the rope is wound around the pole, but a player who is behind can reset the score by pushing the rope windings off of the pole. Also, twirling the rope in order to rack up point windings would be awkward—and possibly even dangerous to the other

player, depending on how long the pole is. Lastly, the ball serves no purpose in this case. Ponytail holds the rope while White Hat holds the ball from which the pole goes up.

Ground-pole-rope-ball is the best and therefore receives five stars. Players can accumulate point windings by hitting the ball past the other player, and gravity and the pole's height prevent the player who is behind from unscrupulously resetting the score. This is the configuration that is used in real life. Back to Cueball and Megan, who are getting ready to play a regular game of Tetherball.

In the title text a fifth alternative is mentioned, where there is no rope, and instead a second pole rotates freely around a joint made out of a ball:

Ground-pole-ball-pole is mentioned to be fun, because if you shake the pole stuck in the ground, the loose one connected via the ball could begin whipping around dangerously. Whether this is actually entertaining depends on whether you get hit by it... Again, You would not be able to keep score in the same way as regular tetherball, but you could count who got hit by the second loose pole first, or, for instance, the first to 10 hits. Alternatively, you could score a point by managing to make the free pole make a complete rotation without your opponent managing to change its direction. If the pole is not padded, or made of a soft material, this would likely be dangerous,[citation needed] or at least painful. Randall also remarks that the ball would probably get

torn apart as it acts like a joint between the two poles. No rating is given, but, given that he calls it fun, at least 3 stars might be expected.

#2664: Cloud Swirls

August 26, 2022
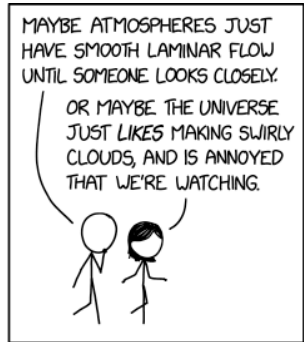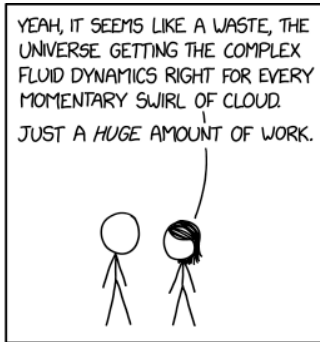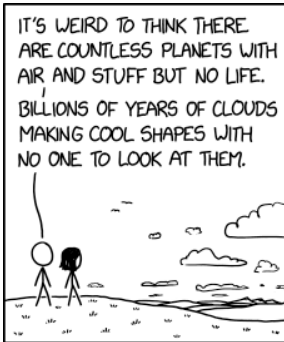
'Why did you get into fluid dynamics?' 'Well, SOME planet has to have the coolest clouds, odds are it's not ours, and rockets are slow.'

Explanation

There are planets. A lot of them, even. Like our planet, for instance. In 3D software, depictions are often rendered at a lower quality when the viewer's perspective is far away from them, to save on computational work for aspects the user can't clearly discern. This idea is built upon here, conceivably to suggest how simulations of universes might seem different than base reality to observers within them.

In this comic, Cueball and Megan theorize that complicated cloud formations occur naturally on other planets in other solar systems. On planets with no observers to look at the clouds closely, our universe, or the simulation thereof, might not afford to render a visual depiction of the atmosphere in higher quality. Meteorologists and physicists on Earth might notice that such exoplanet atmospheres do not obey formal Navier-Stokes fluid dynamics, but instead reflect low-quality corner-cutting of such calculations, such as exhibiting only smooth laminar flow instead of turbulence, its alternative. The foregoing would make sense if the Universe were actually simulated by a computer and the being(s) who are running the physics simulator, or have coded our universe, wanted to speed things up.

Of course, most people do not think that the Universe is a simulation, but society does not know that it isn't a simulation with absolute certainty. There is a direct

relationship between the question of the simulation hypothesis in metaphysics and Pascal's wager in theism, i.e., whether God(s) exist(s), with weighty implications regarding free will and determinism, such as which raise the question of non-naturalist compatibilism.

Megan proposes an additional theory that the universe is intended to make cool swirly clouds, and that the presence of life to observe these clouds is a bothersome coincidence. This goes against the theory that the Universe must not care about making cool swirly clouds since it wants to skimp on their fluid dynamics calculations. Even among followers of the simulation hypothesis, ascribing sentiment, emotion, or motivations to the entire universe is usually considered to be in jest, because of the dissimilarities between sentient beings and cosmologically distant sets of galaxies.[citation needed] This jest forms the basis of the comic's humor. Neither ascribing motivations to the Universe nor positing the purpose of a constructed simulation of our reality are falsifiable hypotheses subject to scientific inquiry, although they may imply logical and mathematical inferences.

The title text includes a dialogue with one person asking another why they got into fluid dynamics. The answer implies that the motivation was to simulate the clouds of planetary atmospheres unreachable by today's rocket technology.

#2665: America Songs

August 29, 2022

PLACES WHOSE NAMES SCAN TO "AMERICA," SO THEY
CAN BE SUBSTITUTED INTO SONGS SUCH AS:

AMERICA THE BEAUTIFUL
GOD BLESS AMERICA
NEIL DIAMOND – AMERICA
WEST SIDE STORY – AMERICA
THE GUESS WHO – AMERICAN WOMAN
GREEN DAY – AMERICAN IDIOT

SASKETCHEWAN
OLYMPIA
ONTARIO
MONTPELIER · ACADIA
LAKE MICHIGAN
SCHENECTADY
CENTRALIA
CONNECTICUT
LAGUARDIA
PEORIA
ANNAPOLIS
YOSEMITE
COLUMBIA
VIRGINIA BEACH
LOS ANGELES
COLUMBIA
VIDALIA
THE VILLAGES
ST. PETERSBURG
MIAMI BEACH

ALGERIA
ARMENIA
MONROVIA   BYZANTIUM
BRASILIA   ASSYRIA
AUSTRALIA   BERINGIA   SOKOVIA   LOTHLORIEN   THE METAVERSE
VALENCIA   ANTARCTICA   ANDROMEDA   SUBNAUTICA   ECONOLODGE

Juraaaassic Park, Juraaaassic Park, God shed his grace
on theeeee

Explanation

Many songs, particularly those written by Americans, contain the word "America." Randall has listed 6 such songs: "America the Beautiful", "God Bless America", Neil Diamond's "America", "America" from the Broadway musical West Side Story, the Guess Who's "American Woman" and Green Day's "American Idiot". These songs usually either praise the United States for its perceived virtues or mock it for its perceived flaws. Regardless of the content of the song, one could likely sing such songs replacing each usage of the word "America" or "American" with another four-syllable word or phrase with emphasis on the second syllable, without disrupting the cadence or meter of the song. Words and phrases like this are said to "scan" with the word "America," which means to conform to that metrical pattern.

The comic provides a list of such names, most of which are locations. While some share virtues or flaws with the United States, most would fit into songs about the United States poorly, and only some are prominent enough to justify a song praising or mocking them. So the substitution is humorous for most of the examples. Other examples include Afghanistan, Turkmenistan, Uzbekistan, Tajikistan, Liberia, Nigeria, Bolivia, Siberia, Somalia, Albania, Bulgaria, Colombia, Cambodia, Armenia, Australia, Estonia, Mongolia, Romania, Slovenia, Slovakia, South Africa, El Salvador, the Alamo, the Netherlands, and the Philippines.

Note that inhabitants of some real-world locations mentioned in this comic do not pronounce their names in a way that scans with "America". Also note that the adjective form of many of the places listed either does not exist or does not fit the same rhythmic structure as "American". (For instance, while "Antarctican Idiot" scans with "American Idiot", "St. Petersburgian Idiot" does not; meanwhile, "Canada" does not scan with "America", but "Canadian" does scan with "American" and was in fact used as such in Weird Al's parody, "Canadian Idiot".) In these cases, it would be necessary to use the noun form of the name to preserve the song's meter.

The title text provides an example: substituting "Jurassic Park" for "America" in the song "America the Beautiful".

A similar comparison in "scanning" was made in 1412: Teenage Mutant Ninja Turtles.

Table of names matching the rythmic meter of America[edit]

#2666: Universe Price Tiers

August 31, 2022

	UNIVERSE LITE™	UNIVERSE STANDARD®	UNIVERSE PRO®™
PRICE	FREE	$14.95/MONTH	$49.95/MONTH
ADS	YES	YES	NO
NUMBER OF ANGELS THAT CAN DANCE ON THE HEAD OF A PIN	4	64	4,096
FREE WILL OR DETERMINISM	DETERMINISM	FREE WILL	FREE WILL
COSMIC SPEED LIMIT	65 MPH	300,000 KM/s	UNLIMITED
IF A TREE FALLS IN A FOREST AND THERE'S NO ONE THERE TO HEAR...	NO SOUND	SIMPLE BEEP	FULL SOUND
MEANING OF LIFE	UNKNOWABLE	UNCERTAIN	CLEARLY EXPLAINED
SOUND OF ONE HAND CLAPPING	[NONE]	[NONE]	KAZZAP!
AGING AND DEATH	MANDATORY	MANDATORY	OPT-IN
DOES GOD PLAY DICE WITH THE UNIVERSE?	YES, AND HE CHEATS	YES	NO
BAD THINGS...	HAPPEN TO GOOD PEOPLE ONLY	HAPPEN TO GOOD AND BAD PEOPLE	DON'T HAPPEN
WHAT HAPPENS TO THOSE WHO SOW THE WIND	REAP THE WHIRLWIND	REAP THE WHIRLWIND	LOTS OF CROPS EVERYWHERE

In Universe Pro®™ the laws of physics remain unchanged under time reversal, to maintain backward compatibility.

Explanation

Philosophers have posed many questions in trying to understand the nature of the universe. Some of these have become well-known in popular culture; while some are deliberately open-ended, several others are presented as a choice between two or more options and are assumed to have a single answer, the debate being about which is correct. In this comic, Randall proposes that the answers to these questions are instead not fixed, but vary according to a tiered subscription business model, as seen in many business pricing schemes, particularly in software. In this model, the no-cost tier gets you a universe experience of a lower quality, while at higher tiers better options are available for a cost - for example in the highest tier the processes of aging and death are "Opt-in" rather than "Mandatory". It is not clear from the comic who is supposed to be paying these subscription fees, or to whom they are paid (presumably the developers or maintainers of the universe, or the hypothesized simulation thereof), or whose experience of the universe is supposed to be affected.

The universe does not have a subscription model,[citation needed] but some of the categories on the chart that refer to observable properties (such as the speed limit or existence of the Uncertainty Principle) indicate that ours is the Universe Standard® subscription. Other specified settings may not entirely match our user experience. Possibly a high-tier installation has the option to restrict itself to selected

lower-tier behaviors if it is considered more useful.

The title text refers to the concept of T-symmetry in physical laws. Most properties of our universe are asymmetric, meaning that the property changes if time is reversed (e.g. the entropy of the universe decreases as time flows backward). Randall again makes a reference to software subscription models in a play on words as the Universe Pro®™ sub appears to have laws that maintain "backward compatibility".

Given that Universe Standard is most in line with the non-facetious observations, and assuming the price tag has not changed since day one, whoever is paying for this subscription has paid 2.470×1012 dollars, given that current estimates place the age of the universe at 13.77 billion years old..

#2667: First Internet Interaction

September 02, 2022
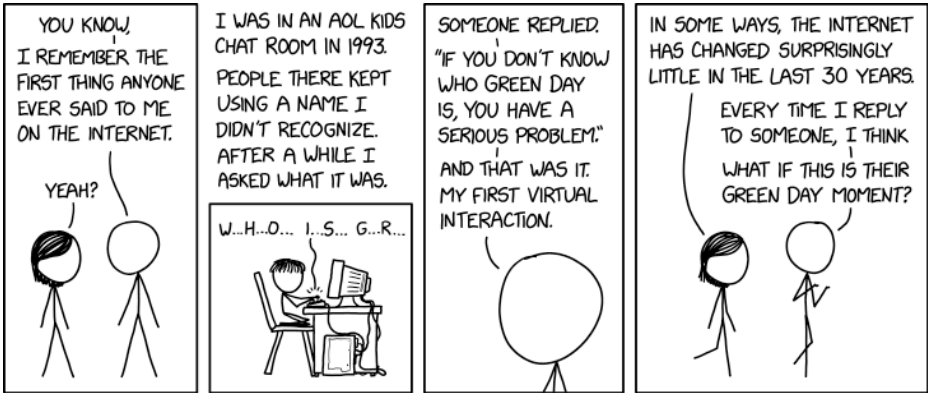
To that stranger on the KOOL Tree House chat room, I gotta hand it to you: You were, ultimately, not wrong.

Explanation

In this comic, Cueball, very likely as an autobiographical representation of Randall, describes to Megan the first time he interacted with a group of people unknown to him over the internet; in an AOL chat room for children called the "KOOL Tree House chat room" in 1993, when Randall was about nine years old. He read a discussion about Green Day, asked who they are, and was told that not knowing was a serious problem. As Megan says, judging people for lack of pop culture knowledge has remained typical online behavior.

Green Day is an American rock band formed in the East Bay of California in 1987. In 1993, they were still known merely as an independent punk band, and a year away from releasing their major-label debut album Dookie, their first mainstream success. Anyone, especially a nine year-old, not recognizing the band in 1993 would be perfectly normal. After 1993, Green Day would go on to be a widely popular and influential rock band with many acclaimed albums.

This initial online social interaction was a significant formative experience for Cueball, molding his online behavior ever since, in that it still causes him to consider his correspondents' perspectives when communicating. The social dynamics at play are reminiscent of the mathematics of others' perspectives described in 1053: Ten Thousand. Relating the personal experience of an oversized effect from a casual insult is humorous because

the extent to which early experiences affect people can be both ironic and profound.

The title text indicates Cueball agrees with the reply to the question. This is humorous because it is effectively Cueball admitting that something is very wrong with him, possibly coincidental with and unrelated to knowing that specific piece of trivia. Alternatively, Cueball could have come to believe Green Day is culturally important. If this story is autobiographical, Randall could have hence become a Green Day fan, or at least acquired more than a passing knowledge of their œuvre, recently mentioning their song "American Idiot" in 2665: America Songs.

#2668: Artemis Quote

September 05, 2022

THIS IS ONE OF MY FAVORITE HISTORICAL QUOTES—THE FIRST WORDS SPOKEN BY AN ARTEMIS ASTRONAUT ON THE MOON.
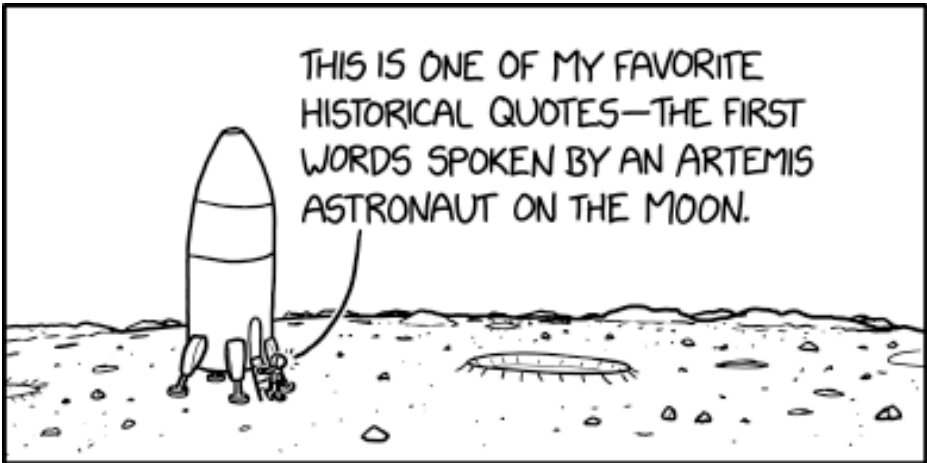
NEIL ARMSTRONG'S "MAN"/"A MAN" QUOTE CREATED A LOT OF HISTORICAL CONFUSION, AND I THINK IT'S OUR DUTY TO EXPAND ON THAT LEGACY WITH ARTEMIS.

Another option: "It is an honor to be the first human to set foot on the moon."

Explanation

The Artemis program is a series of planned space missions that will land people on the Moon and begin to set up infrastructure for a permanent crewed presence. People first landed on the Moon in 1969 as part of the Apollo program. They have not been back since 1972. When Neil Armstrong became the first person to walk on the Moon, he famously said, "That's one small step for man; one giant leap for mankind." However, he was intending to say, "That's one small step for a man; one giant leap for mankind [emphasis added]." The audio recording omits the word "a", making the sentence confusing, as "man" and "mankind" have the same meaning when referring to all people.

That the word was apparently elided by Armstrong in the excitement, changing the meaning of the historical phrase, is controversial and thus humorous. Subsequently, Armstrong and others have blamed insufficiently tuned voice activity detection hardware circuitry intended to save power in radio voice transmission, but NASA engineers, third-party historians and their hired experts have never been able to corroborate that explanation. Armstrong later said he hoped, "history would grant me leeway for dropping the syllable and understand that it was certainly intended, even if it was not said," and, on p.126 of the June 1982 edition of Omni, "the 'a' is implied, so I'm happy if they just put it in parentheses."

Randall suggests that the first Artemis astronaut to set foot on the Moon has a duty to utter an even more confusing quote, saying the sentence, "This is one of my favorite historical quotes — the first words spoken by an Artemis astronaut on the moon," aloud as they step onto the Moon. That would be confusingly self-referential, as if they were alluding to something from the past. The phrasing would also be confusing to a person hearing it quoted, as it would sound more like a statement about the quote than the actual quote itself. This is very unlikely, and funny merely as a recommendation. If it actually happened, it might be both hilarious and scandalous.

While the comic's lunar lander has similarities to the current plans for the Artemis lander, it is a generic drawing, perhaps in homage to classic space science fiction, with the exit portal at an unlikely position near the base of the SpaceX Starship lander.

The title text suggests an alternate phrase by which the Artemis astronaut could say being the first (rather than 13th) human on the Moon is a great honor. People hearing this quote in the future could assume that Artemis was the first crewed mission to the Moon. It could feed into contemporary conspiracy theories that the Apollo landings were faked (or even spread suspicion that the first twelve astronauts on the Moon were not human), furthering the confusion.

This comic coincides with the canceled launch of Artemis 1, an uncrewed test mission which will serve as

the start of the Artemis program. The mission was intended to launch on 29 August 2022, and later on 3 September 2022, but was repeatedly postponed due to a series of technical problems. It finally launched on November 16th. On December 13th, the spacecraft successfully splashed down back on Earth.

In 893: 65 Years, Randall made a graph showing the number of living people who had been on the moon, and estimated the day when zero would be alive. At that time 9 of the 12 were still alive. Upon this comic's release, only four are still among the living.

#2669: Things You Should Not Do

September 07, 2022

UPDATES TO MY "THINGS YOU SHOULD NOT DO" LIST,
BASED ON WHAT I LEARNED WRITING *WHAT IF? 2*
(OUT 9/13, xkcd.com/whatif2)

THINGS YOU SHOULD NOT DO
(PART 3,647 OF ????)

#156,812 EAT TIDE PODS
#156,813 WALK ON STILTS IN A THUNDERSTORM
#156,814 SET OFF FIREWORKS AT A GAS STATION
#156,815 FEED YOUR CAT TREATS THAT ARE THE EXACT SHAPE AND TEXTURE OF A HUMAN HAND

——————————— NEW! ———————————

#156,816 LEAN OVER A GEYSER VENT AND TRY TO LOOK DOWN INTO IT
#156,817 FLY A HOT-AIR BALLOON OVER A FIRING RANGE
#156,818 PEEL AWAY THE EARTH'S CRUST
#156,819 TRY TO PAINT THE SAHARA DESERT BY HAND
#156,820 REMOVE SOMEONE'S BONES WITHOUT ASKING
#156,821 SPEND 100% OF YOUR GOVERNMENT'S BUDGET ON MOBILE GAME IN-APP PURCHASES
#156,822 FILL A LAVA LAMP WITH ACTUAL LAVA
#156,823 DRINK THE BLOOD OF SOMEONE WITH A VIRAL HEMORRAGHIC FEVER
#156,824 EAT MEAT FROM RABID ANIMALS
#156,825 PERFORM YOUR OWN LASER EYE SURGERY
#156,826 TELL CALIFORNIA POULTRY REGULATORS THAT YOUR FARM IS SELLING POKEMON EGGS
#156,827 FUNNEL THE ENTIRE FLOW OF NIAGARA FALLS INTO THE OPEN WINDOW OF A PHYSICS LAB
#156,828 PUMP AMMONIA INTO YOUR ABDOMEN
#156,829 SUSPEND YOURSELF INSIDE A 10-METER BALL OF SUNSCREEN AND FALL INTO THE SUN

Now I'm tempted to start telling people that I secretly don't actually know how to do any physics calculations, and so all the answers in What If are based on me actually trying to do the thing and then reporting what happened,

but phrased as if it's hypothetical.

Explanation

This comic references various questions submitted by people and used in the what if? blog, What If? and What If? 2 books. In particular, promoting Randall's new book, What If? 2 (released 6 days after the date of this comic publication). This comic has a list of things not to do, an extension of a previous list, and is purportedly things Randall discovered as he was doing research for his book. The page What If? chapters contains the titles, publishing date, thumbnail, question, and explenation for each article. Many of the acts described under the "new" section of the list are depicted in these thumbnails (see table below); others are references to examples or hypotheticals explored within the articles. The entries are all in order of their appearance in the book.

The title text says that Randall is tempted to tell people that all the things in the book were things that he actually tried to do, not that he calculated the solutions for their problems. Many of the questions and answers in his new book are borderline impossible and/or fatal to attempt in real life.[citation needed]

Table of things you should not do[edit]

#2670: Interruption

September 09, 2022

...AND THAT'S WHEN YOU KNEW SHE HAD BETRAYED YOU?

YEAH. SHE PICKED UP THE MONEY AND WALKED OUT.

TO THIS DAY, I DON'T KNOW IF SHE PLANNED IT ALL.

BUT THERE WAS ONE MOMENT THAT MAKES ME THINK, MAYBE SHE DID.

JUST BEFORE SHE DISAPPEARED, SHE PAUSED AT THE DOOR, LOOKED BACK AT ME, AND SAID,

HEY—

IF I EVER SEE YOU AGAIN,

TURN LEFT AT THE NEXT LIGHT.
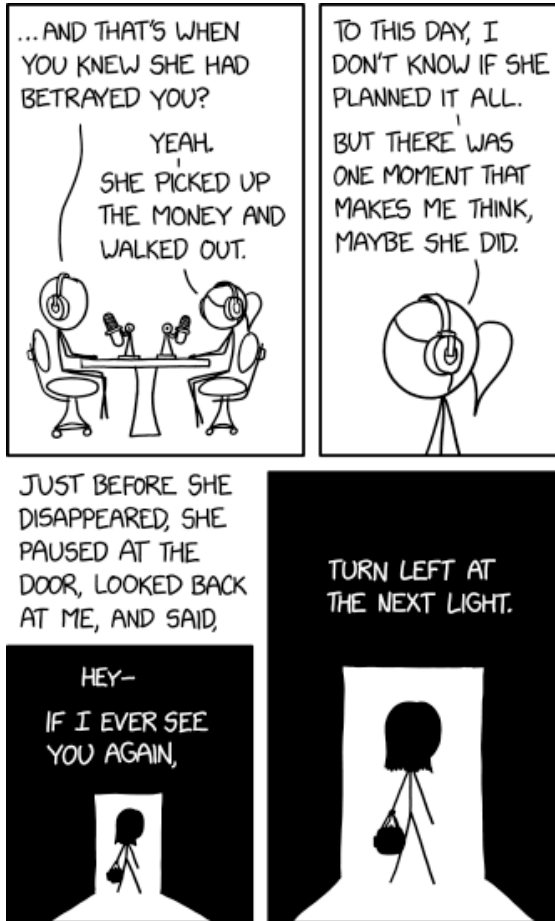
IT'S SO DISORIENTING WHEN A PODCASTER HAS A VOICE THAT'S SIMILAR TO MY NAVIGATION APP.

It's been extra bad ever since my GPS got stuck on Phoebe Judge mode.

Explanation

This comic is about listening to a podcast while driving with GPS navigation using speech synthesis for turn-by-turn driving instructions. Car entertainment systems and SatNav-enabling devices (if connected to the car's audio feed) typically allow the SatNav to interrupt whatever else is being played, so that directions can be heard clearly. It's usually easy for the driver to recognise such instructions due to the sudden change in characteristics of the voice and the switch in contextual flow. However, if the synthetic voice is similar to the speech that was playing, it may be hard to distinguish between the two, especially if the navigation instructions seem to coincide with the interrupted speech. In cases like this, the listener might think that the driving instructions are part of their podcast.

Cueball is interviewing Ponytail for the podcast, and she tells a story about a woman who betrayed her. Just when she is about to tell what the betraying woman said to her before she left with the money, which might have revealed if it had been planned in advance, the GPS instructions interrupts and delivers a driving instruction blocking out the last part of a sentence.

The comic suggests Randall misinterpreted those driving instructions as part of the story being told in the podcast because the GPS voice sounds similar to Ponytail's voice. The comic illustrates the instructions as if they were part of the story from the podcast.

The title text suggests this confusion worsened after Randall's navigation instructions voice got stuck emulating Phoebe Judge, known for the Criminal and This Is Love podcasts, implying he often listens to her.

#2671: Rotation

September 12, 2022
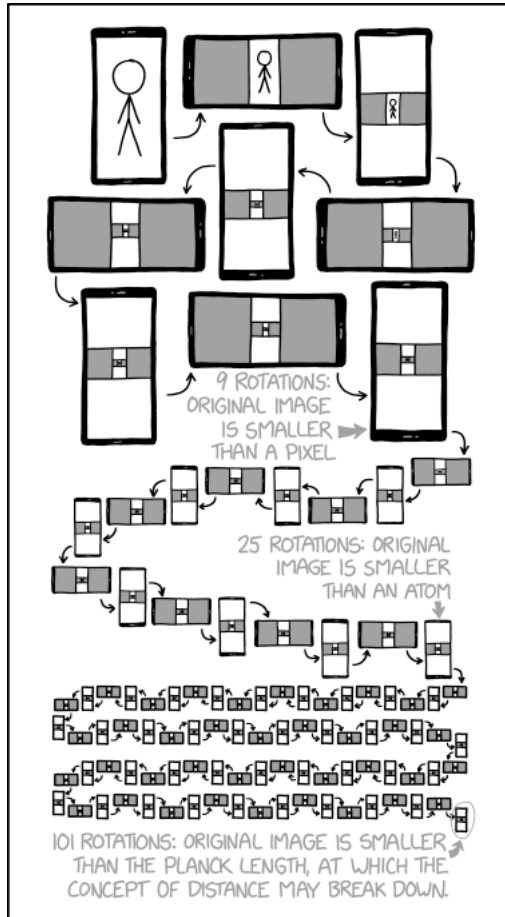
PHONE TIP: DON'T ROTATE AND SCREENSHOT AN IMAGE TOO MANY TIMES OR IT WILL BECOME LOST IN THE QUANTUM FOAM OF THE UNIVERSE.

It's okay, we can just feed the one-pixel image into an AI upscaler and recover the original image, or at least one that's just as cool.

Explanation

This is another one of Randall's Tips, this time a phone tip. This tip claims that rotating a phone and taking a screenshot too many times will cause an image to disappear into nothingness and warns the user against doing so. The camera and the display both have limited resolutions, so the detail of the original screenshot at the center of the image will be reduced as it approaches the range of a few pixels, hence the original image will be lost before it reaches the sub-pixel range. This is funny because the default resolution of contemporary camera phones can be too large to meet size requirements for e.g. mobile phone Multimedia Messaging Service, web file uploads, or email attachments, so one or two steps of this awkward procedure are sometimes necessary. Other comics such as 878: Model Rail also use recursion as limits.

For a fuller explanation of the concepts involved, including Planck units, often associated with the topological quantum foam of string theory, please see this CGP Grey video. For an explanation of topological string theory, see 2658: Coffee Cup Holes. Please see also 1683: Digital Data for an analogous image processing concept.

The title text refers to producing photographically likely higher resolution images from lower resolutions, an active area of current research. Because reducing the resolution of an image is a lossy process, results obtained

through such processes will not be able to perfectly recreate the original. Machine learning can be used to calculate how images of known photographic subjects (or e.g. anime-style art, in the case of waifu2x) behave under certain types of noise or reduction in size, so that images of those kinds can be upscaled in a way that, if not perfectly recreating the original, at least is a faithful representation, but when the image is scaled all the way down to one pixel, everything except a small amount of data about the image's overall color is lost, making reconstructing the original image impossible. Randall disclaims that, because the AI upscaling is based on ingesting a large corpus of human-made art (with subjects that we find 'interesting' or at least meaningful being predominantly represented), the AI will produce an image that is at least as cool as the original image was, and in fact some image generation AIs actually work on a similar principle — for example, "reverse diffusion" AIs are trained by teaching them to reconstruct images from noise, at which they can produce entirely new images by being fed actual noise. He could also be making a pun on color temperature, which the upscaler will be able to match to the original image. The "enhance button" for upscaling images is a common trope in movies and television, especially in crime and science fiction stories.

Mathematical corner[edit]

The scale reduction caused by a rotation can be approximated. If a is the width of the picture and b its height, the reduction is x=a/b, the aspect ratio of the picture rectangle. As can be seen in the comic, the first rotation leaves two gray areas on each side of the

picture that are roughly square. The width of the reduced picture is x*a = a²/b. Each gray area is a (high) by (b-x*a)/2 (wide). This is roughly square, but will not be exactly square unless

This is a quadratic equation, whose only positive solution is √2-1 ≈ 0.414

Returning to the general problem: the reduction is geometric, so that after nine rotations, the picture will be reduced by a factor of x^9. Since this is "smaller than a pixel", the original screen resolution is fewer than $(1/x)^9$ pixels. It is not stated whether it is the width, height, or area of the original picture that have been reduced to "smaller than a pixel".

25 rotations reduces a lot further and logarithms are useful to compute that. Let L be log(a/b), a negative number since a/b is less than 1. If the original screen is 10cm wide, its reduced picture will be x^25 times smaller in width. The comic tells us that the picture is now "smaller than an atom" (typically 10^-10m). If referring to the width, then 25L is less than about -9.0 using base-10 logarithms.

After 101 rotations, the reduction will be x^101, and the picture is now "smaller than the Planck length". The log of the Planck length is about -34.8, so 101L is less than -33.8.

Significantly we know that 100 rotations was not enough, so 100L is greater than -33.8. If we split the difference and say that 100.5L is equal to -33.8, we get an aspect ratio a/b just about 0.461. Multiple popular phone sizes are within the range, including the iPhone X or XS both with an aspect ratio of 1125/2436 ~ 0.4618.

#2672: What If? 2 Flowchart

September 13, 2022
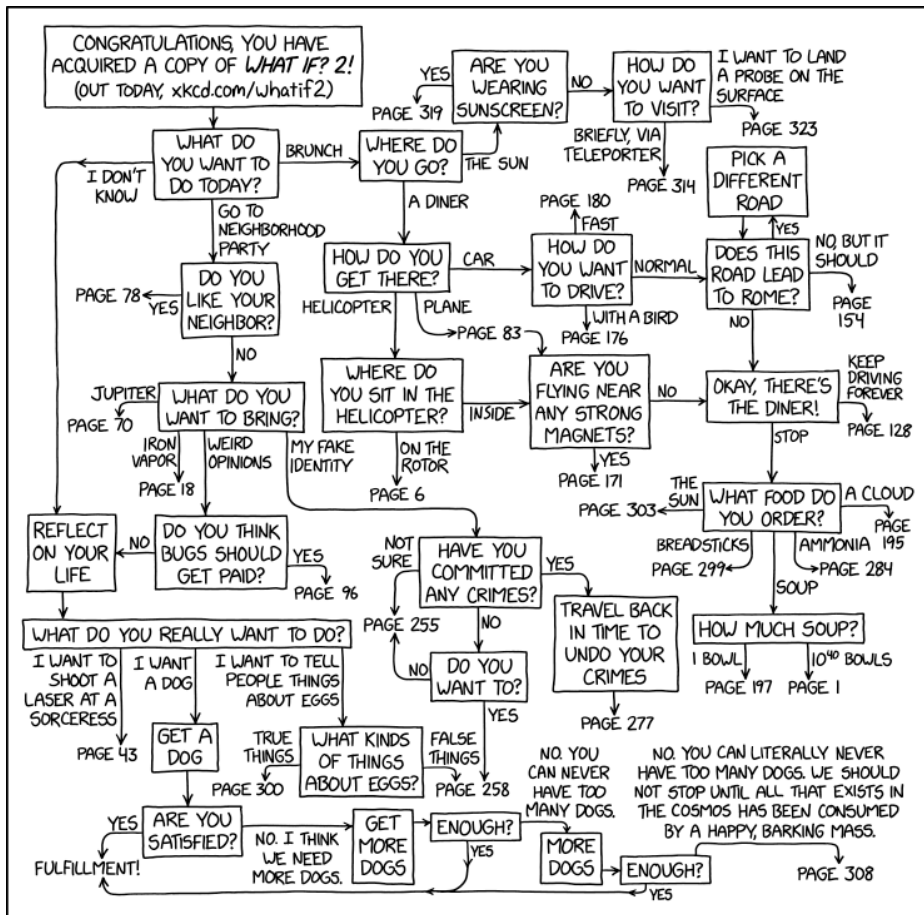
Don't worry, the dogs are all fine. That's actually kind of the problem.

Explanation

This comic celebrates the release of Randall's new book, What If? 2, which was released on the same day as this comic: Tuesday, September 13, 2022. The comic thus appeared on a Tuesday, replacing that week's normal Wednesday release to coincide with the release day. The header text also changed that day to shout out that the book was released on that day. (It had been counting down the last week, from less than a week, three days and one day while the previous comics 2670: Interruption and 2671: Rotation was on the front page — the latter only for one day due to the Tuesday release).

While announcing that his What If? 2 book is finally out (the entire comic is a link to the books page on xkcd), Randall gives us a flowchart we can follow to find an article in the book relating to the situation in the flowchart. Once a relevant possibility is reached in the flowchart a page number in the book is given. It thus assumes the reader plans to do something that the advice in What If 2 could be helpful for, which hopefully is highly unlikely. See the table below for explanations on the individual options in the flowchart.

The title text refers to the loop near the bottom of the flowchart, which involves a series of questions asking if the reader wants a progressively larger number of dogs. The number of dogs offered increases several times, and if that is sufficient the flowchart ends with fulfillment. Eventually it will have an option for the scenario where

all in the universe is consumed by dogs, which directs to page 308 of the book. The title text references this last option by assuring the reader that all of the dogs are doing fine, but goes on to state that in itself could cause problems. For instance, those dogs could impede the progress of all life on Earth and elsewhere and/or reproduce and create an even larger population of dogs.

#2673: Cursed mRNA Cocktail

September 16, 2022

EVER WONDERED WHAT IT WOULD BE LIKE TO DRINK THE NEW COVID BOOSTER?

THIS RECIPE APPROXIMATELY RECREATES THE TASTE AND NUTRITIONAL PROFILE!

(NOTE: DOES NOT PROTECT AGAINST COVID.)

"...WHAT? EWW."
—CDC SPOKESPERSON

"PLEASE STOP."
—DR. ANTHONY FAUCI

INGREDIENTS

2 CUPS WATER
3 TBSP MAYONNAISE
¼ TSP MSG OR NUTRITIONAL YEAST
1 TBSP SUGAR

DIRECTIONS

POUR 1 CUP OF WATER INTO A BLENDER. ADD THE MAYONNAISE AND MSG. BLEND UNTIL SMOOTH.

POUR THE OTHER CUP OF WATER INTO A GLASS. ADD THE SUGAR AND 1 TSP OF THE MIXTURE FROM THE BLENDER. STIR WELL.

SERVE IN SHOT GLASSES.

Serve one each to guests whose last cursed cocktail was more than 2 months ago.

Explanation

This comic describes a recipe to approximate the molecular composition of certain mRNA-based vaccines, in drinkable form. It contains the variety and relative concentrations of the simple molecular constituents found in the injectable mixture. Coronavirus mRNA vaccines contain mostly water, with some mRNA, a few fats (e.g., a PEGylated lipid and cholesterol), sugar (sucrose), and tromethamine buffer to stabilize pH. The cocktail contains mostly water, some sugar, fats, either an amino acid salt or biological and genetic material, and the other constituents of mayonnaise.

The word cocktail in the context of drugs can mean several things, including medically designed combinations of drugs. That's not so far in concept from the current formulation of COVID-19 booster, which targets both the original and BA.5 variants of the virus.

Like much of what we eat or drink, the stomach and intestines will neutralize much of the complexity of either the vaccines or this ersatz replica of them, reducing them to simpler components of some nutritional value. For the vaccine to work, it has been designed to be injected into the body e.g. intramuscularly to bypass the hostile environment of the human digestive system. While there are similar vaccines administered as a nasal spray, the fragility of mRNA in the digestive system has curtailed the search for ingestible analogs. Randall's

replacement mixture is nontoxic, and contains water, proteins and calories, all important nutritional components. Because it doesn't contain a complete spectrum of essential amino acids, vitamins, and minerals, you can't live on it alone.

The CDC (Centers for Disease Control and Prevention) is the US national public health agency. They make recommendations about vaccine use. Dr. Anthony Fauci has been the chief infectious disease advisor to numerous US Presidents and has often been interviewed regarding COVID-19 vaccines.

The instruction to serve in shot glasses is a play on words, as "shot" can mean injection in medicine. One jigger is only 0.19 of a cup, so the recipe serves up to five.

The title text suggests the mixture can be served as a "booster" to a prior dose. The comic recommends not redosing within two months of the last attempt. The current mRNA coronavirus booster is approved for use at least 2 months after previous immunization. Too little time between doses of a vaccine may reduce benefit from the booster. However most pairs of distinct vaccines work well if delivered on the same day.[actual citation needed]

This comic coincided with the widespread availability of the bivalent COVID vaccines in the US. It's another entry in a series of comics related to the COVID-19 pandemic, specifically regarding the COVID-19 vaccine. It was, however, almost a year since the vaccines were

mentioned last in 2532: Censored Vaccine Card, released almost 11 month before this one, and more than 8 months since the last comic to directly feature COVID-19, which was 2563: Throat and Nasal Passages, that came out as the first comic in 2022. It's also another comic with cursed items. Disgusting drinks served in shot glasses, and related to people with colds, are mentioned in the volume section of 526: Converting to Metric.

#2674: Everyday Carry

September 19, 2022
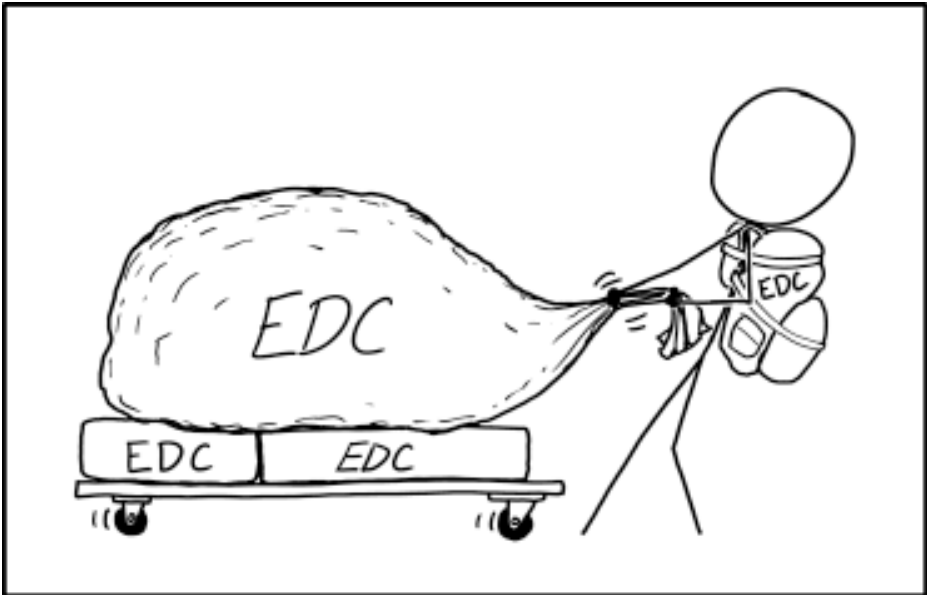
IT WAS HARD WORK COLLECTING ALL THE
EVERYDAY CARRY PRODUCTS ON THE INTERNET,
BUT NOW I'M FINALLY READY FOR ANYTHING.

Someday I just know I'm going to encounter a problem that requires 500 flashlights and 700 knives with weird holes in them, and on that day I won't be caught unprepared.

Explanation

"EDC" stands for everyday carry, which is a term for tools and other objects intended to be carried around during the course of everyday life. The notion is that a relatively small number of versatile items, designed to be easily portable, can prepare you for a wide variety of possible situations. Typical items include such things as wallets, cell phones, small flashlights, pocketknives and multi-tools. Items specific to a person's occupation, lifestyle or other needs might also be included.

While the concept of regularly carrying items that you might need is a very old one, the abbreviation "EDC" has come to signify a subculture, well-represented on the internet which promotes self-reliance and preparedness for almost any situation. As with so many subcultures, this movement has spawned a thriving market in selling products explicitly intended for "being carried every day". Any internet search will reveal thousands of products, of various levels of quality and utility, marketed to people interested in EDC. Stylized pocketknives, 'tactical' flashlights and tools purporting to fulfill multiple functions are common examples.

Rather than carefully consider the relative advantages of each of these pieces of gear, Cueball seems to have taken the advertising of such items at face value: he's purchased them all, and attempts to carry them all with him every day. The result is that he has so many items that he not only needs to wear a heavily augmented backpack, he also

needs to drag around a cart carrying boxes and a massive bag, presumably filled with the thousands of pieces of gear he's purchased. Such a strategy obviously defeats the original purpose of EDC, which is to select a set of items that's both portable and useful, but such is the result of taking internet marketing literally.

In the title text, he expresses confidence that he'll be vindicated by encountering a situation in which his massive collection of items will be useful. He also makes clear that, having bought all the items available, his collection is wildly redundant, having hundreds of flashlights and pocketknives. While it's quite common to encounter a situation in which a knife or flashlight is needed (sometimes even two might be useful), a situation where hundreds would be useful is difficult to imagine.

#2675: Pilot Priority List

September 21, 2022

PILOT PRIORITY LIST

——————— STANDARD SECTION ———————

1. **AVIATE**
   MAINTAIN CONTROL OF THE AIRCRAFT

2. **NAVIGATE**
   FIGURE OUT WHERE YOU'RE GOING

3. **COMMUNICATE**
   STAY IN TOUCH WITH ATC AND OTHERS

——————— EXTENDED SECTION ———————

4. **DECORATE**
   MAKE THE COCKPIT FANCY

5. **ACCELERATE**
   SEE HOW FAST YOU CAN GO

6. **ROLLER SKATE**
   ZOOM DOWN THE AISLE

7. **EXFOLIATE**
   SCRUB AWAY DEAD SKIN

8. **SUBLIMATE**
   TURN DIRECTLY TO A VAPOR

9. **POLLINATE**
   FLY LOW TO STIR UP POLLEN

10. **CONGRATULATE**
    YOU'RE DOING A GOOD JOB FLYING A PLANE!

CELEBRATE: Serve passengers tiered cakes shaped like the airspace class diagram

Explanation

The "ANC" Pilot Priority Checklist is a list of three guidelines, sorted by priority, that pilots should follow to prevent them from being distracted. Failing to follow it might make the aircraft crash or suffer other problems. As a mnemonic device, all the activities end in -ate.

By deferring less important activities until the prior need is deemed satisfied, the immediate dangers of flight into terrain (uncontrolled and controlled flight into terrain) are reduced — as the pilot's current circumstances allow — and yet can provide for addressing other hazards.

Randall humorously "extends" this standard list with other -ate checklist items that pilots could do if they're not too busy aviating, navigating and communicating. These extra tasks range from somewhat hilarious to physically impossible or dangerous; see the table below for explanations. These actions should generally not be taken, as they could distract the pilot and prevent them from reaching the cabin in case of an emergency, or vaporize everyone inside along with portions of the airframe.

The title text adds another -ate item to the checklist: Celebrate, whereupon congratulatory cakes are served to the passengers. The "inverted tiers" refers to the airspace class diagram used in the United States, used by planes circling over airports. The class diagram starts with a small circle over the airport and then becomes wider in

one or two steps at higher altitudes. When depicted graphically, this looks like an inverted tiered cake, as opposed to a regular tiered cake. Randall suggests that after having congratulated yourself for flying an aircraft, you could then celebrate by serving the passengers cakes in this inverted shape. It would, however, be unsuitable for an aircraft to serve cakes that are smaller at the bottom than at the top because of turbulence.

Table of extended priority items[edit]

#2676: Historical Dates

September 23, 2022

HISTORICAL RECORDS SHOW MILLIONS OF BUSINESS TRANSACTIONS OCCURRED ON DEC 30TH, 1899.

THIS ECONOMIC ACTIVITY SPARKED THE DIGITAL AGE, CULMINATING IN A "DATA FESTIVAL" ON JAN 1ST, 1970, WHEN MANY EARLY DIGITAL FILES WERE CREATED.

1899   1970
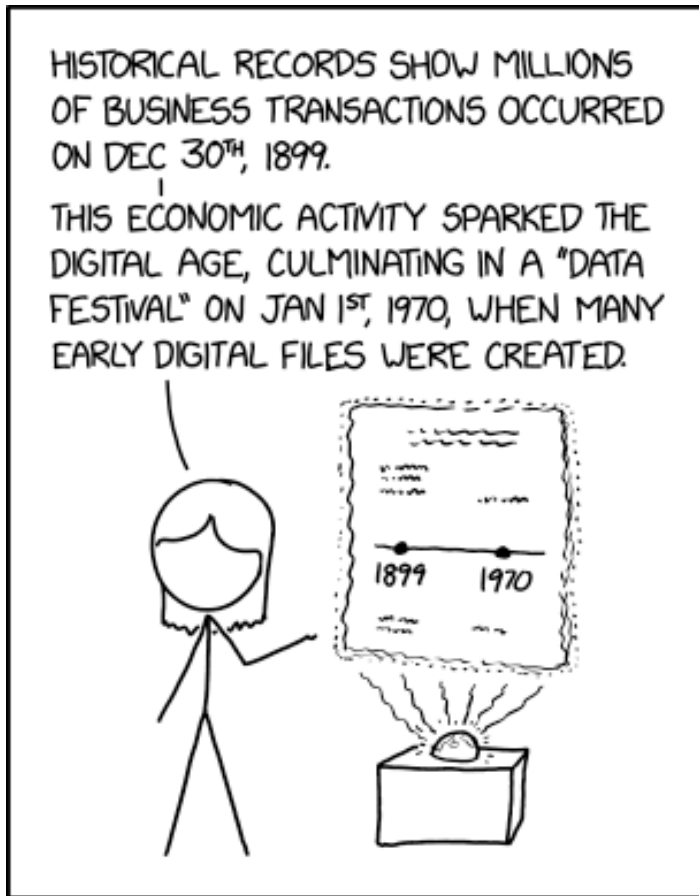
IT'S GOING TO BE WEIRD WHEN HISTORIANS FORGET WHY SOME DATES SHOW UP A LOT.

Evidence suggests the 1899 transactions occurred as part of a global event centered around a deity associated with the lotus flower.

Explanation

Many files and database entries contain a date. When it is not set, it often defaults to the first day in the system. The two dates listed below are mentioned as "significant" in the comic.

Dec 30th, 1899[edit]

Dec 30th, 1899 comes from a spreadsheet date compatibility issue between Excel and Lotus 1-2-3 (referenced in the title text.) Spreadsheets store dates as sequential numbers so that they can be used in calculations. In Excel, by default, January 1, 1900 is number 1 . Based on that, Excel's integer date representation would be the number of days that have passed since December 31, 1899. However, because of a bug intentionally carried over from Lotus 1-2-3 where it counts February 29, 1900 as a day even though it actually was not , for any day since then, Excel's integer date representation is actually the number of days that have passed since December 30, 1899. Most other spreadsheet applications copied the behavior of Excel to maintain compatibility with it. This leads to the value of 0 in some applications (notably Open- and LibreOffice Calc and Google Spreadsheets) being interpreted as Dec 30th, 1899. Similarly, Microsoft Visual Basic and Visual Basic for Applications (VBA) interpret 0.0 as Dec 30th, 1899.

The historian in the comic presents some research wrongly based only on the number of entries created on those dates. This confusion on the part of the future historian only grows in the title text, where they make the claim that Lotus 1-2-3 is, in fact, religious imagery related to some sort of deity, potentially a lotus god, around whom the '1899 event' took place. This may be

poking fun at the trope that anthropologists attribute any behavior they can't explain to religious ritual.[actual citation needed] This historian's confusion may have been at least partially due to China's White Lotus Religion.

Jan 1st, 1970[edit]

Many operating systems and software store dates as Unix timestamps, which are defined as the number of seconds since Jan 1st, 1970, 0:00 UTC. When data entry neglects to provide a value, the system may be programmed to treat it as 0; consequently, an unprovided timestamp value is interpreted as Jan 1st, 1970 thereby creating the illusion of an "activity spike" on that date.

#2677: Two Key System

September 26, 2022
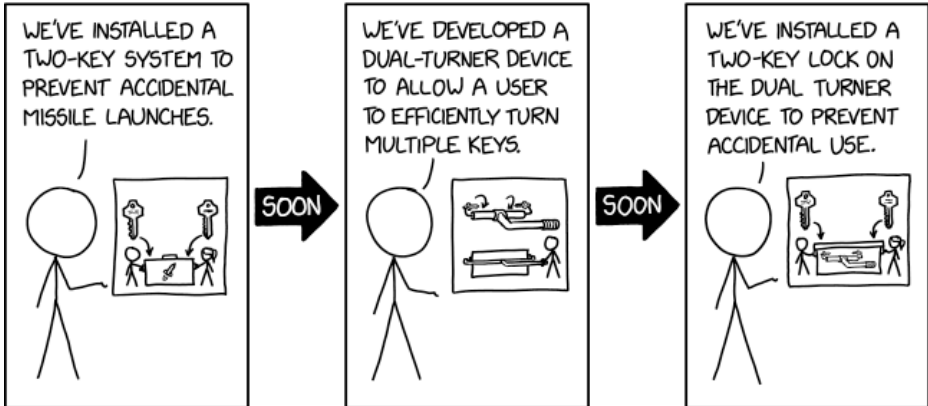
Our company can be your one-stop shop for decentralization.

Explanation

As an allegory, the comic relates the results of software development to the reputed safeguards of nuclear missile launch systems.

Such precautions include the need for two independent operators for authorization, to prevent honest mistakes or the rogue actions of lone-actors. This is the kind of procedure used at a launch site where two duty officers each need to turn their respective keys simultaneously. The physical distance between the keys ensures that an individual cannot turn both keys simultaneously, or initiate the sequence without the second person.

In relation to software development, the inconvenience caused by such precautions (like account passwords and two-factor authentication) has prompted the development of methods to make the process easier (like autofilling passwords or website cookies keeping a user logged in for multiple visits). Similarly, the system in the comic is made more convenient by using a dual key-turner that circumvents the need for two users to turn the keys.

And thus we find out that the thing used to make the safeguards less of a nuisance actually defeats the purpose of the safeguards. As with website passwords, where the use of a computer or device by someone else could allow them to use the autologin capabilities, or even to view all passwords used locally and take away for their own use,

the whole point of the deliberately included security factor has been negated. It was only the perceived need for two independent operators that created the initial situation of requiring two separated keys, or indeed any keys at all!

Hence, after a further cycle of development, in order to restore the security of the two-key system, the two-key turning device (rather than being removed or made unworkable) is provided for use but only if it can be removed from a secure cabinet (labelled as giving access to the 'key turner', much as the original unit was labelled as giving access to a missile) with the requirements to open it being... two separate keys to be used at the same time! This could be seen as the same as password managers being introduced, either as a part of a browser or third-party add-ons, which automatically provide the user's passwords for any given access attempt but only when they are given a password (or other security factor) themselves.

And so, rather than removing a 'problem', a new safeguard is added which does the exact same thing as the original, the possible nuisance (but hopefully also the necessary element of security) included.

Password management, as a process, is substantially similar to key management: Common failure-modes for both passwords and keys, include forgetting your own long-term passwords (especially if you changed computers after asking your computer to remember your passwords for you) which is functionally similar to

misplacing your keys, or tending to use just a single password or key for every lock (which, if ever compromised in one situation, may lead to being compromised across many others). A Password Manager can reduce such issues, as it can be capable of 'spitting out' or transfering login details at will and letting you use many different passwords (even generating and using the kinds of passwords nobody should be able to guess, or remember!) across your many different websites, etc. But this passkey storage must itself be secure, and so should be functionally accessible perhaps only through use of a 'master passkey' or some other kind of authentication process, which may be subject to the same issues of forgetting, copying, or theft. Similarly, a central lockbox full of keys (such as those used at some car dealerships), can make handling multiple keys much easier, while introducing a single point of failure in the event that lockbox is illicitly accessed. Various forms of multi-factor authentication, plus auxiliary authentication methods for password recovery/reset, go some way to alleviate these challenges, at the expense of further intermediary steps and hardware requirements; but the balance between ease of use and security is never quite so simple and universal.

The title text mentions a one-stop-shop for decentralization. The drive to make use of "one-stop-shops" (such as a website aggregating searches for the best insurance) and also to decentralize (in this case not relying upon any one vendor, even that single aggregator who might actually not be the best aggregator)

is another self-contradiction — because a one-stop-shop is by definition centralized.

The comic being posted on September 26th may or may not be a reference to Stanislav Petrov correctly rejecting the false detection of an incoming nuclear missile strike from the US on September 26th, 1983. When asked whether or not this reference was intentional, Randall has continuously declined to comment. 2052: Stanislav Petrov Day

For a related xkcd on security and software cycles, see 2044: Sandboxing Cycle.

#2678: Wing Lift

September 28, 2022

HOW A WING PRODUCES LIFT

AIRFLOW SPLITS AROUND THE TOP AND BOTTOM OF THE WING

SPOOKY SKULLS MICROPRINTED ON THE BOTTOM OF THE WING FRIGHTEN THE AIR, WHICH FLEES AWAY DOWNWARD

TOP AIR GOES TO SEE WHAT'S WRONG

BY NEWTON'S THIRD LAW, DOWNWARD DEFLECTION OF AIR PUSHES WING UPWARD
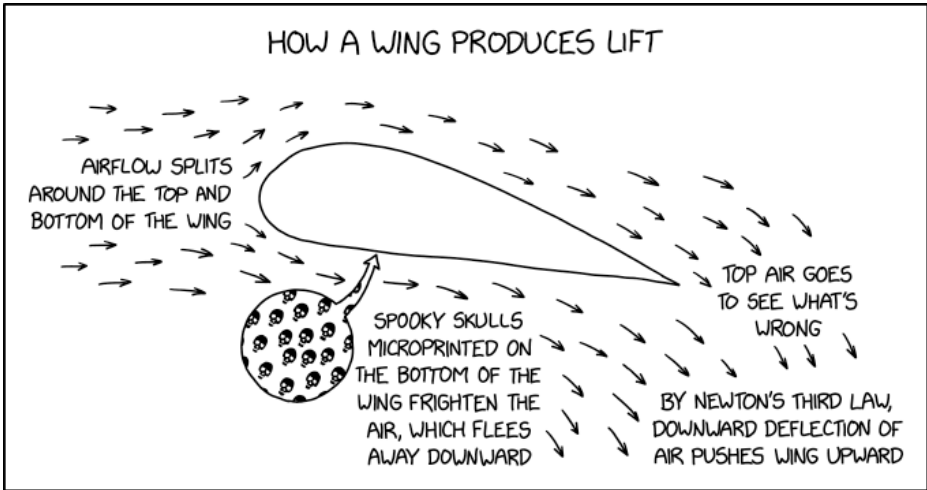
Once the air from the top passes below the plane of the wing and catches sight of the spooky skulls, it panics, which is the cause of turbulent vortices.

Explanation

This comic is a parody of the incomplete explanations given to physics students on how wings produce lift. Specifically, it parodies the equal transit-time fallacy, which states that the air flowing above the wing and the air flowing below the wing have to travel from one side of the wing to the other in equal time, so the air above the wing has to travel faster to keep up with the air below. This assumes that the air above the wing is somehow conscious of what the air below the wing is doing. This assumption of consciousness is taken to extreme parody by the comic, suggesting that the bottom air can be frightened by skulls, that the top air is curious to see what's going on, and that air can panic. In real life, this is not the case.[citation needed]

Wings can produce lift, i.e. an upwards force with which an aircraft is held in the air. One or more of three main reasons may typically be given as to why airplane wings produce lift:

- Bernoulli's principle (Perhaps the most frequently cited/demonstrated as a basic introduction to wing-physics.)
- Angle of attack (The airplane wing angles up so that air is deflected downwards, by the 'ski effect'.)
- Coandă effect (The top is curved, so air going over the wing must curve downwards in order to avoid creating a vacuum above the back of the wing, and by Newton's

third law, this results in an upwards force on the wing.)

The comic references all three of these reasons. Airflow splitting references Bernoulli's principle, while the air at the bottom being scared and fleeing downwards is similar to the effect of air hitting the angled bottom of the wing. The air going over the top curving down references the Coandă effect, although the comic claims that this effect is instead caused by the top-air noticing the bottom-air fleeing downward and goes down to investigate why the bottom-air is fleeing. The mention of Newton's third law is indeed correct, even if the movement of the air is for the wrong reasons. In the title text, it additionally suggests that the top-flow also end up glimpsing the printed skulls, causing it to also chaotically flee, generating a wing's classic turbulent wake.

Randall previously dealt with explanations of wing lift in 803: Airfoil.

#2679: Quantified Self

September 30, 2022

GOOD JOB! YOU HIT YOUR WEEKLY GOAL FOR "TOTAL LENGTH OF YOUR PATH THROUGH SPACE IF YOU MINIMIZE ITS LENGTH BY PULLING IT TAUT, MANEUVERING IT AROUND SOLID OBJECTS BUT NOT THROUGH THEM."
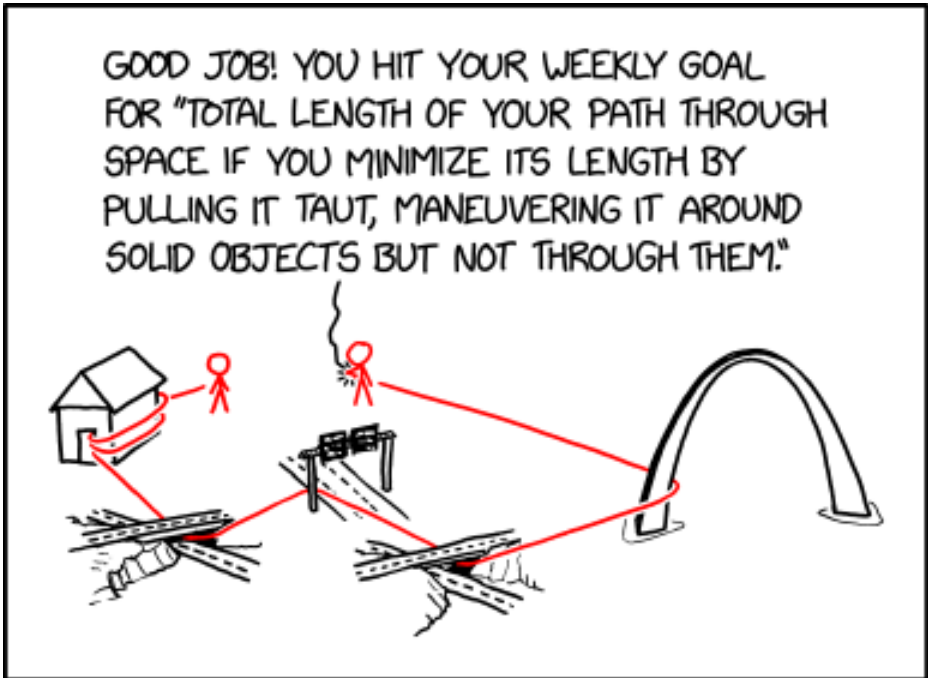
I'M INTO THE QUANTIFIED SELF, BUT ONLY FOR REALLY ARBITRARY QUANTITIES.

It's made me way more excited about ferris wheels, subways, car washes, waterslides, and store entrances that have double doors with a divider in the middle.

Explanation

Cueball embraces the quantified self, a popular philosophy promoting monitoring yourself with devices and data in the hope of helping your well-being. He does so in a unique and absurdly humorous way, with help from a smart watch or handheld mobile device. Randall's caption indicates he is interested in the quantified self for unusual quantities.

Typically, fitness apps and wearable devices will track the number of steps that users take and distances walked or run, along with other measurements such as heart rate, blood oxygenation level, blood pressure, and mood. This is to encourage users to be more physically active. However, Cueball has chosen to track a modified version of this metric, in which his path is post-processed by contracting it as much as possible without it passing through anything solid. Ordinarily, people begin and end their days in bed; in this case, it can get 'caught' where Cueball has passed through topological tunnels. (See 2658: Coffee Cup Holes and 2625: Field Topology for details.) In the comic strip, we see that, over the course of his week, Cueball has looped through his house thrice and crossed under two highway overpasses, a highway sign, and apparently the St. Louis Gateway Arch before almost returning home.

This comic appeared two days after Google's announcement that Maps Directions will be sortable by sustainability, along with their support of

self-quantification for sustainability when shopping for automobiles, used goods, and food. This is noteworthy because of tech industry discussions between employees and executives comparing sharply increased profits and productivity from work-from-home to the value of coastal region commercial office space holdings and leases, relative to scope 3 emissions.

An "imaginary thread" connecting a person to where they came from (as portrayed in this comic, distinct from a mystical silver cord or red thread of fate) has been attested to by people experiencing obsessive-compulsive disorder (OCD.) See also 100: Family Circus and below for further elaboration.

The title text mentions several things that would make the red path longer: passing one way through a tube such as a water slide; a tunnel, such as a subway or car wash; riding on a ferris wheel, or entering a building through one door and exiting another. In all cases the imaginary string would be "captured" and make the total distance longer.

OCD interpretation[edit]

The quantity Cueball measures can be recognized as a specific type of OCD where people feel like they have an imaginary string connecting them to where they come from.[actual citation needed] This is similar to describing 4-D paths in Minkowski space relative to the observer's frame of reference.

As they move around, that string gets entangled and they feel the urge to untangle it. When they enter a car, they feel the need to

exit the car from the same door, to avoid that the string gets trapped by forever passing through the car. When they enter a building, they feel they need to exit using the same staircases and doorway(s), to avoid entangling the string in the building. Some situations, like turning around a lamp post, are OK because you can imagine removing the loop over the top of the lamp post, such that it is not really entangled.

Cueball tries a new approach to deal with this OCD by integrating it in his quantified self. He defines precisely how to measure the length of the imaginary string, reduced to its minimum, and chooses this as a quantity to monitor. Unlike most people with this OCD, who feel the urge to minimize the length, Cueball takes the opposite stance trying to maximize the (optimally minimal) length of the string. By defining as a target to achieve a given length every day, he creates a drive to embrace situations that entangle the string. This drive opposes the natural compulsion to avoid them and hopefully cancels it. The joke of the title text is that Cueball now becomes overly interested in all the things that are disturbing for people with the OCD.

#2680: Battery Life

October 03, 2022
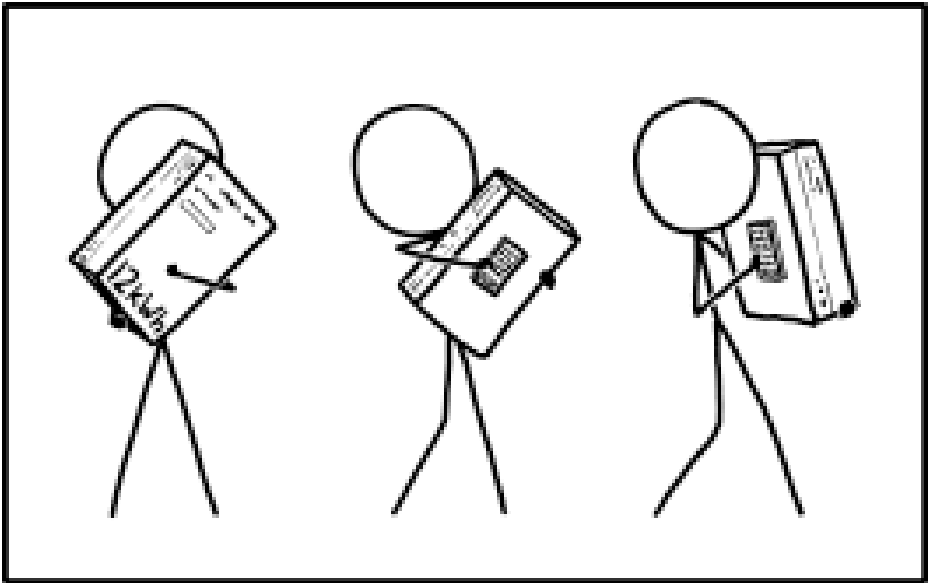
PLUGGING IN MY PHONE IS A PAIN, SO I GOT ONE WITH A 100LB BATTERY, AND WHEN IT RUNS OUT OF CHARGE EVERY FEW YEARS I JUST UPGRADE.

It's okay, I'm at 10%, so I'm good for another month or two.

Explanation

Smartphones run on batteries that require frequent charging; they may also be frequently replaced with a newer model by their user, though battery life is only one of several reasons why they may do this. In this comic, instead of charging his phone every day for a few years and then buying a new phone, Cueball has obtained a phone with a battery big enough to last supposedly until the phone will be replaced after a few years. This appears to make for a phone of cumbersome weight and size. According to the caption, 10% of battery life corresponds to 1–2 months; this suggests a total battery life and hence product life of 10–20 months, which is less than two years. A 'few' is generally more than that, even in the world of xkcd. (This assumes that he'd be 'good' right up until 0%. He could be just talking about being generally unconcerned until it reaches 5%, say, from which point he knows he'll have a similar further amount of time to start seriously thinking about arranging the full replacement, and all that this entails.) More practically, a smartphone requires around 2 kWh per year (assuming this is not otherwise an untypical phone in terms of power requirements), so this 12 kWh battery could have been expected to last even longer.

A 12 kWh battery weighing 100 pounds (45 kg) has an energy density of 264.6 Wh/kg, about equal to the high-estimate of the energy density of lithium-ion batteries of 100–265 Wh/kg. However, it is well below the practically achievable energy densities of

(non-rechargeable, as befits the application) zinc-air batteries at around 400 Wh/kg. Unfortunately, Self-discharge means that if this battery is lithium polymer, it will lose on average 5% of its charge per month, which totals to 46% lost each year. If this were a non-rechargeable battery such as lithium metal, its battery life could be much longer.

This comic appeared on the same day that the European Union standardized charging adapters for mobile phones.

This may be a commentary on very large external portable charging devices. At present (October, 2022) the largest cell-phone sized charging devices hold almost 40000mAh and can weigh almost a pound. Even larger devices are available weighing over 40 lbs in different form factors. We buy cell phones because of their small size and convenience,[citation needed] and end up buying extra external battery power for them that adds significant extra weight and bulk.

Portable (on wheels) 12 kWh lithium-ion batteries do exist but typically weigh over 250 lbs and tend to lack ports to plug a phone directly into. Roughly 100 lb portable power stations can have capacities as high as 6 kWh and can be used to charge a typical smartphone directly hundreds of times.

#2681: Archimedes Principle

October 05, 2022

UH, ARCHIMEDES, WHY IS THERE A BUCKET OF WATER WITH A GOLD CROWN HIDDEN IN THE BOTTOM?

IT'S MOSTLY SILVER. REPLICA OF THE KING'S CROWN. HE'S COMING HERE LATER, AND I HAVE A PLAN.
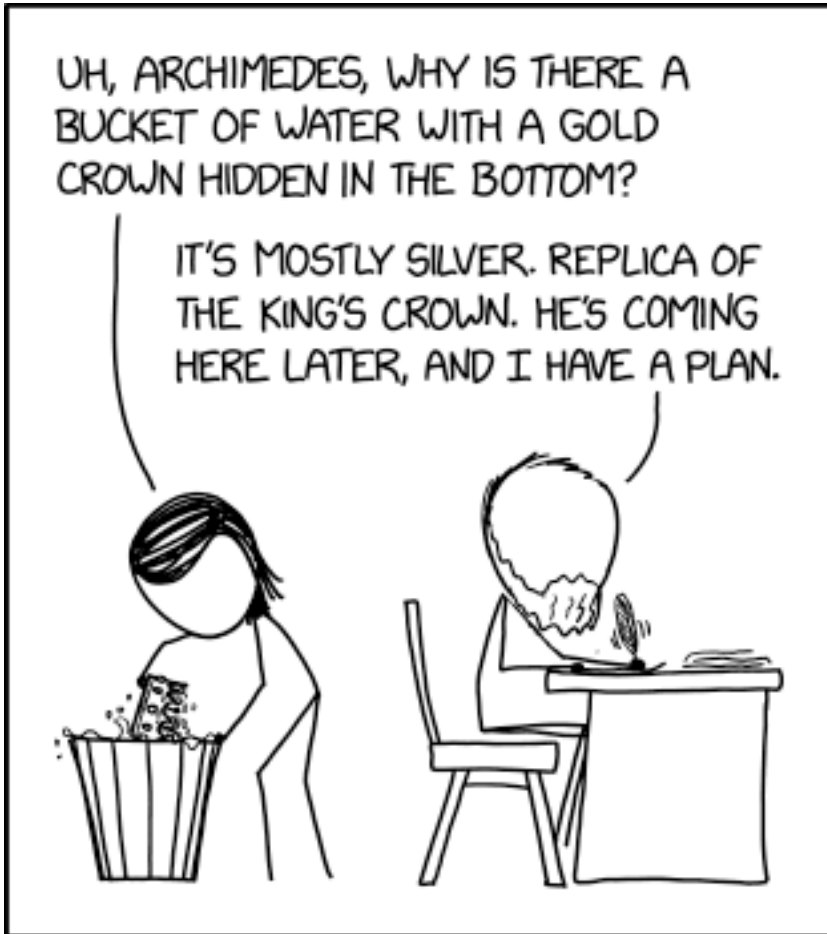
ARCHIMEDES INVENTS THE HEIST.

"I've always wanted to run naked through town, but I don't want to get in trouble with the king or be remembered by history as a weirdo. I wonder how I could ... EUREKA!"

Explanation

Archimedes was a foundational mathematician and scientist who lived in the 3rd century BCE. It was recorded that he was tasked by his tyrant king, Hiero II of Syracuse, with determining whether a votive crown made by a local goldsmith actually contained all the gold the king had provided for it, or whether the goldsmith had substituted an equal weight of silver for the more-valuable gold. Archimedes knew he could solve this problem if only he could compare the crown's weight to its volume; since any silver in it, being only about half as dense, would occupy more volume than the gold. Despite knowing this, Archimedes didn't know how to measure the volume of the crown, which was highly irregularly shaped. According to legend, as Archimedes was getting into a bath one day, the bath overflowed. Archimedes realized that the volume of water displaced by any immersed object, including his body and the crown, was equal to the submerged volume of the object, and thus he could establish the crown's volume; a crown made with substituted silver of equal mass would displace more water than the supposed gold version would. This insight led him to solve the king's problem (and determine that the goldsmith had in fact cheated the king out of some gold). Legend also says that upon having this insight, he went running naked down the streets of Syracuse shouting "eureka!", Greek for "I have found it!" - a word now associated with sudden insights.

In the comic, Archimedes' insight doesn't involve

science, but is a plan for self-enrichment. Evidently, he has concealed a less-valuable gold-plated or gold-alloy crown in the tub of liquid, and plans to swap it for the real crown when 'measuring the volume'. This implies that the king's crown turns out to be, in fact, pure gold, but Archimedes will report it to be adulterated with silver, in order to steal the gold crown for himself. This is claimed to be the invention of the heist. While theft has no doubt existed since property has existed, a "heist" implies a complex plan, often based on deception and carefully planned operations, as is typical of heist films.

The title of the comic, "Archimedes Principle", refers to a different but related insight of Archimedes, that the upward buoyant force that is exerted on a body immersed in a fluid is equal to the weight of the fluid that the body displaces. It may also relate to the particular twist of morality being observed by this version of Archimedes, in that it seems not to be against his principles to defraud a king, and (incidentally?) besmirch a particular master-craftsman.

According to the title text, Archimedes's eureka moment wasn't when he discovered how to measure the crown's volume, but when he realized that he could use this discovery as a pretext for running naked through town, something he'd always wanted to do.

#2682: Easy or Hard

October 07, 2022

	ACTUALLY PRETTY EASY TO FIND OUT	VERY HARD, BUT THERE HAVE BEEN RECENT BREAKTHROUGHS	EXTREMELY HARD, CURRENTLY UNSOLVED
SOUNDS BORDERLINE UNSOLVABLE	HOW MUCH DOES THE EIFFEL TOWER'S GRAVITY DEFLECT BASEBALLS IN BOSTON?	WHAT TIME OF YEAR DID THE CRETACEOUS IMPACT HAPPEN?	HOW CAN RELATIVITY BE RECONCILED WITH QUANTUM MECHANICS?
SOUNDS PRETTY HARD, BUT YOU'D ASSUME THAT SOMEONE KNOWS	WHERE WAS MARS IN THE SKY FROM PARIS ON THE DAY THE EIFFEL TOWER OPENED?	HOW MANY ANTS ARE THERE?	HOW DOES TYLENOL WORK?
SOUNDS LIKE IT WOULD BE EASY TO LOOK UP	HOW TALL IS THE EIFFEL TOWER?	HOW DOES GENERAL ANESTHESIA WORK?	WHY DOES YOUR HAIR GET A STATIC CHARGE WHEN YOU RUB IT WITH A BALLOON?

"Friction-driven static electrification is familiar and fundamental in daily life, industry, and technology, but its basics have long been unknown and have continually perplexed scientists from ancient Greece to the high-tech era. [...] To date, no single theory can satisfactorily explain this mysterious but fundamental phenomenon." --Eui-Cheol Shin et. al. (2022)
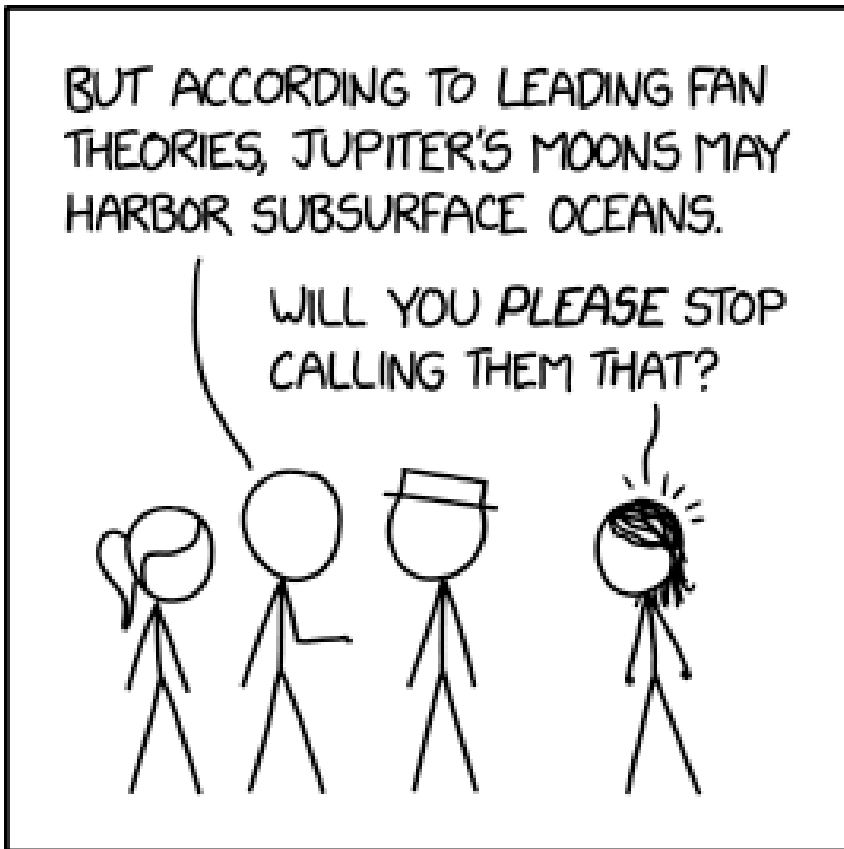
Explanation

This comic uses a table to compare the perceived difficulty of various questions with how easily they're answered in real life. Randall has a long history of comics with similar themes, comparing perceptions to reality. In this case, both the perception and the reality are divided into three levels of difficulty, giving a total of nine categories. Accordingly three of the problems listed are effectively as difficult as one would expect, and the remaining six are not. All three of the questions whose answers are "actually pretty easy to find out" relate to the Eiffel Tower, though there's no apparent theme among the other six questions.

It's likely that this comic was at least partially inspired by writing the books How To, What If?, and What If? 2, the latter of which was published just a few weeks before this comic. These books involve answering very elaborate questions from a scientific point of view. This process likely emphasized that some really strange questions are actually relatively easy to answer, while some questions that seem simple continue to confound scientific knowledge. What if? 2 mentions the fact that no one understands why static charges separate.

#2683: Fan Theories

October 10, 2022

BUT ACCORDING TO LEADING FAN THEORIES, JUPITER'S MOONS MAY HARBOR SUBSURFACE OCEANS.

WILL YOU *PLEASE* STOP CALLING THEM THAT?

HOW TO ANNOY SCIENTISTS: REFER TO ALL HYPOTHESES AS "FAN THEORIES"

The universe fandom is great. Such sweet and enthusiastic people.

Explanation

This is another comic on How to annoy people. Here Cueball annoys Megan, a Scientist, by referring to the hypotheses that there are subsurface oceans on some of Jupiter's Moons, as "fan theories".

A fan theory is an unofficial hypothesis about a fictional work from enthusiasts instead of the official authors. Fan theories may include non-canonical background information for, or continuations of, official narratives. Since humanity is not the "author" of the universe, all thoughts and writings on the nature of the universe are, almost by definition, non-canonical fan ideas. Fan theories have been referenced before in 1401: New.

In this comic, Cueball refers to scientific hypotheses as "fan theories." Scientists might consider this as undervaluing their work, because scientific hypotheses are usually the result of much more serious research than the authorship of fiction. Charismatic cranks often obtain undeserved recognition for supposedly scientific hypotheses, so being lumped in with charlatans or pseudoscientists could be perceived as insensitive to rigorous scientists. Once again, Randall has attempted to devise a new way to annoy scientists. However, many if not most professional scientists are aware of similarities between hypotheses pertaining to fiction and non-fiction.

By referring to rigorous scientific studies as "fan theories"

Randall is also elevating the experience of fandom. Though they are typically not supported by research institutions, tenured faculty positions, or grant funding, fandom communities often demonstrate a high degree of skill in literary criticism including evidence gathering, philosophical interpretation, and generative writing. This continues the trend of building connections between disciplines in STEM, social science, and the humanities.

This comic appeared a few days after renewed suggestions that life may exist within one of Saturn's moons.

The title text may be facetious, having to do with unwelcoming or inconsiderate fandoms (or scientists who are annoyed at being called "fans of the universe"), or it could be sincere.

#2684: Road Space Comparison

October 12, 2022
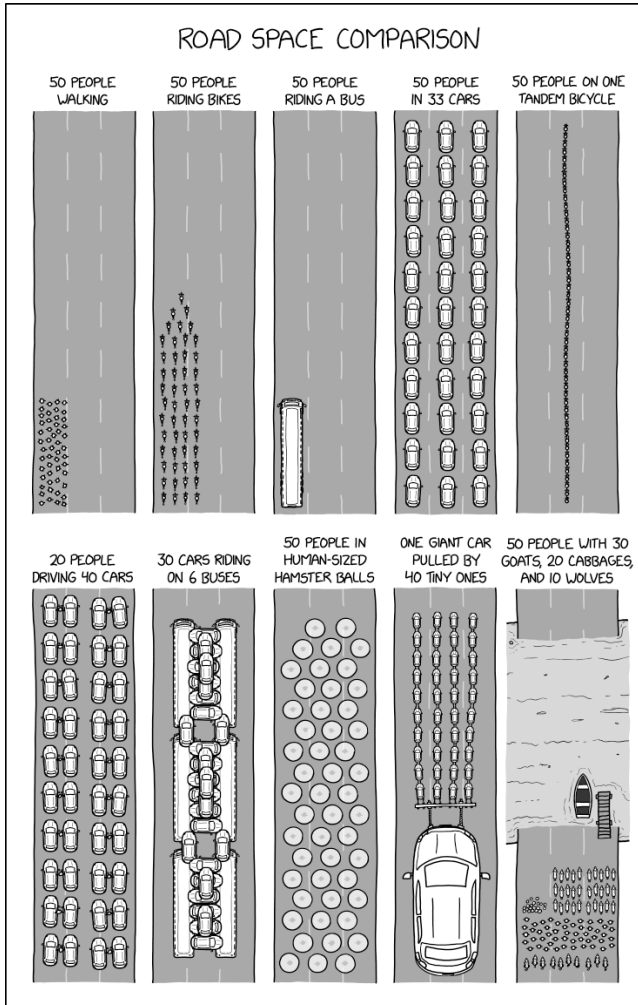
I wonder how hard it would be to ride an electric scooter in a hamster ball.

Explanation

The comic is a parody of a common comparison done in arguments for public transport and walkable cities - the amount of usable space taken up by cars and car-centric infrastructure that could be eliminated for other useful public amenities. The first of these may be from 1965.

The first 4 images are common, real-life comparisons involving people walking, people on bicycles, public transport, and cars, which distinctly show how cars take up significantly more space for the same number of people than the other methods of transport. However, from this point the comic becomes more and more absurd in its comparisons.

- The 5th image shows 50 people on what is reported to be a tandem bicycle, although it seems more likely to actually be a string of trailer bikes, due to it not being rigid and the separation from one person to the next is larger than is typical for tandem bicycles. This would obviously be impractical in a city due to the tandem's sheer length and it would not be able to work with fewer than 50 people due to its sheer mass. The longest compound cycle holds 52 people, while an actual tandem bicycle exists that has at least 35 seats.

- The 6th one involves 20 people driving 40 cars, with each person driving 2 cars at a time by straddling them in the middle. Besides being unwieldy and impractical, it would also be extremely dangerous as the cars could

go out of control at any time. Perhaps the cars would be a paired mix of left-hand-drive and right-hand-drive models, although with enough push-rods/levers (to also reach the traditional foot controls, and also gear sticks unless fully automatic) this might not be as important. However, even if the cars were perfectly safe to drive, it would be unsafe to drive them on most roads; roads with only one lane per direction are common, everywhere from city streets to exit ramps, and attempts to drive a pair of cars down such a road side by side are unlikely to end well.[citation needed] (Of course, worse than any of these petty safety concerns is the fact that each person takes up twice as much road space, making most infrastructure a bit less efficient. Of all the examples, this is the most wasteful of space, with the entire road being taken up by only 20 people.)

- The 7th one has 30 cars riding on 6 buses by stacking them on top of each other. Assuming the same people-per-car/bus from the earlier examples, this arrangement would have about 345 people riding on the same road! (Unless, of course, the buses are carrying 30 cars instead of their normal passengers.) In addition, people getting out of the cars when they reach their destination would be a problem for most cars in this arrangement due to them being stacked under other cars or surrounded by them. And as in the previous example, it would be impossible to safely drive anywhere without two clear lanes...and the body count would be considerably higher.
- The 8th panel has 50 people in hamster balls. Randall

has shown his interest in human sized hamster ball transportation before, and indeed, for some people, this might be an enjoyable way to traverse a road, provided no other hamster balls try to drive into you and knock you off the road, and other traffic that could pose a greater hazard has been eliminated.

- The 9th panel has 40 tiny cars pulling a big one. Such feats of strengths are a common sight while setting world records, so maybe this is a world record attempt by the cars in question. It is unknown how many people fit in the big car; judging by its size, it likely fits more than a single bus and less than three. It is also unclear whether the tiny cars can fit a human driver, or if they would need to be driven remotely.

- The 10th panel is a 50 person variation on the classic wolf, goat and cabbage problem (which has been referenced before in 589: Designated Drivers, 1134: Logic Boat, and 2348: Boat Puzzle) except this one involves 30 goats, 20 cabbages and 10 wolves trying to cross a section of road that is underwater, using a single boat. The fact that there is a conveniently placed dock at the edge of the water suggests that this is a ford with provision for those crossing by foot, or at least that the road gets flooded often enough to warrant a permanent dock to be installed. It is not known how many people (or cabbages for that matter) the boat fits, but since humans significantly outnumber the goats, cabbages and wolves, it seems like a much simpler problem, though not necessarily without difficulty.

The initial bicycles and singular bus are actually (mostly)

using the left-hand lane of the three shown, for whatever reason. This would not be unusual on British highways or other countries using their system, whether the lanes seen are just one of the directional carriageways of a multi-lane split highway or the centre-lane is a gantry-signed 'tidal lane' of a fully two-way street. Yet people who have to walk on a road (due to no footway) are advised to walk facing oncoming traffic (the right-hand side, in the same jurisdiction) and not bunched up. It would be interesting to know why Randall, much more familiar with US road conventions, would have offset these various road-users the way he did (rather than hogging the central lane, or across the entire highway width as he did with the other diagrams in the series).

The title text proposes a problem related to another alternative form of transport — the electric scooter. Randall wonders how well an electric scooter would function when run inside the hamster ball. While this could function like a spherical monowheel, it might also be very dangerous.

#2685: 2045

October 14, 2022

...AND THEN AFTER THE ONE IN 2024, THERE'S ANOTHER ON AUGUST 12, 2045.

WE'RE IN! WE CAN INVITE OUR KIDS, ASSUMING WE HAVE ANY.

I'LL CREATE AN EVENT. DO YOU THINK WE'LL STILL BE USING GOOGLE CALENDAR IN 2045?

SORRY, I'D LOVE TO MAKE IT, BUT I HAVE A THING THAT DAY.

IT'S WEIRD MAKING PLANS FOR ECLIPSES.

"Sorry, doctor, I'm going to have to come in on a different day--I have another appointment that would be really hard to move, in terms of the kinetic energy requirements."

Explanation

The characters are talking about upcoming total solar eclipses. Partial solar eclipses are fairly frequent (2–5 per year), but total eclipses are less frequent (about every 18 months), and most of them will not be in convenient locations for a particular set of people. Cueball seems to be talking about total eclipses visible in much of North America: April 8, 2024 and August 12, 2045. (There was also an annular eclipse on October 14, 2023.) Making plans for eclipses is awkward given the uncertainty present for anything else far in the future, such as whether the attendees will have children by then, and whether the technology they are using to keep track of their appointments (Google Calendar in this case) will even still exist over 22 years in the future.

Black Hat claims he can't make it, as he vaguely and obscurely claims he already knows he has "a thing" on August 12, 2045. People do not usually have events scheduled for precise dates that far in the future in their personal calendars and, combined with the fact that Black Hat remembers this date without checking (but also without specifying what he'll be doing then), implies that this could be another of his grand and sinister plans... or he just doesn't want to go. This might also be a reference to an old Soviet joke.

The title text is someone asking to reschedule a medical appointment to see the eclipse. The eclipse is hard to move because that would require hastening or delaying it

by moving the Earth, Moon or Sun, any of which would require vast amounts of energy.

This was published a year before the next such eclipse in America; so, if you're someone who plans things a year in advance, this serves as a reminder to put it on your calendar.

#2686: Space Adventure

October 17, 2022

SIR, THE ENEMY SHIP IS CLOSING IN!

HELM, HEAD FOR THE BLACK HOLE.

ON MY MARK, FIRE TORPEDOES, PHASERS, AND ALL OUR OTHER WEAPONS AT DIFFERENT POINTS AROUND THE EVENT HORIZON.

LET'S SEE WHAT KIND OF BUDGET THESE SHOWRUNNERS HAVE.

IF I EVER FIND MYSELF IN A SPACE ADVENTURE, I'LL ASSUME I'M A FICTIONAL CHARACTER AND TRY TO PROBE THE STUDIO'S FINANCIAL CONSTRAINTS.

"Sir, it looked really cool." "Oh no--prestige TV. Okay, which of you has a terrible secret that's being slowly revealed to the audience through flashbacks? Just spit it out so we can escape this arc!"

Explanation

This comic references space adventure television series and appear to show a typical scene from such a series: The trope of the vessel (in this case a relatively powerless shuttlecraft modeled after the Star Trek Original Series shuttle Galileo) evading combat with some unseen but presumably more battleworthy enemy vessel by fleeing into some form of 'space geography' that the heroes think, or hope, they can hide in or fly through more successfully than their pursuers can find or follow them in. Oftentimes a negative space wedgie (Deus ex machina) or some nebulous form of canyon-run, but if it is an actual black hole (within which the use of fantastical physics is intended to provide some sort of uncertain plot-armour) then often it's a swirly-effect meant to appear to be some kind of cosmic plughole. And this is the escape-route (or hiding place) that this particular ship seems about to try to take advantage of.

The command to head towards the black hole normally promises some (fictional) manner of breaking physics to survive the phenomenon, but is instead followed up by a command that seems intent to break the Fourth Wall. i.e. assuming that this is a fictional scenario and intending to establish exactly what kind of fictional scenario it is. By attempting to interact with the black hole in the most computationally intensive way possible (firing all kinds of weaponry at it, in distinctly different ways) they 'aim' to find out how thoroughly accurate their fictional existence actually is, potentially to test the in-universe

physics and find out with which method their in the real world unsurvivable situation might be escaped from.

(We can already see that it is the imagery of a black hole (or, rather, the hot matter still visible as swirling around its event horizon) featured in the film Interstellar, a high-budget blockbuster which famously created this particular effect from the calculations of actual professional physicists. Although Randall has also used the actual imagery of a black hole, elsewhere.)

Exactly how this helps the crew and passengers, is unclear, but being genre-aware (or not) can have implications for how characters manage to handle the problems that crop up in their various plotlines. The title text indicates that the resulting effects "looked cool", which may not necessarily indicate particular accuracy to 'real life' but indicates at least that the showrunners are taking this fiction seriously. It leads on to the assumption that there is one key piece of information, that one of those present possesses, which has some bearing on their current predicament. And they are going to be in peril from all kinds of 'monsters of the week' or other nemeses at least until they learn what that is, so perhaps they could skip much of the danger just by a more immediate revelation.

"Prestige TV" is another name for the present Golden Age of Television, which started around the year 2000. Golden Age television shows are more likely to have better special effects (more high-quality post-processed Computer-generated imagery (CGI), rather than 'green

screen' background replacement or even a purely practical effect such as 'suitmation' or other modelling) which contrast greatly with the effects of earlier eras. The ability to show weapons being fired, and even some more intuitive-looking emulation of physics, has improved as the production technologies have improved, and potentially made sufficiently good-looking special effects cheaper — certainly more ubiquitous. This then may be considered a co-indicator towards the tendency of newer and more 'cool' looking shows to also develop complex interwoven season-long (or even whole-series) story arcs, which build upon multiple cliff-hangers and situational developments for the characters involved. This is as a contrast to the more traditional stand alone episodes of drama, from earlier decades, that almost always resolve in precisely the conclusive manner that leaves the characters mostly in the same frame of mind as in the start – such that they arrive fresh in the next episode, or indeed any further episode, under virtually the same pretextual scenario.

The other portion of the title text seems to refer to a relatively common trope of internal conflict being somehow related to external conflict, and the increasingly common trope of having a character with a *mysterious past* they've conveniently forgotten slowly rediscover, and grapple with, who they were, the culmination of that character arc often setting up the group of protagonists to be able to defeat the Big Bad Evil Guy (BBEG) or somehow escape the situation they're in.

#2687: Division Notation

October 19, 2022

Science tip: Scientists hardly ever use the two-dot division sign, and when they do it often doesn't even mean division, but they still get REALLY mad when you repurpose it to write stuff like SALE! ALL SHOES 30 OFF!

Explanation

In this comic there is another one of Randall's Tips, this time a Science Tip, however, it is only mentioned in the title text. See below for more.

This comic pokes fun at some of the ways to write the division operation in math. In this comic, Randall has used A as the dividend (the number being divided) and B as the divisor (the number that A is divided by). Division is the fourth simplest arithmetic operation in mathematics, after addition, subtraction, and multiplication.

The first two of the seven notations shown are the division sign (÷) and the long division notation used for short division and long division in beginning arithmetic. (Note: division typography is only used in some countries, and there are different notations in the non-English speaking world). These methods of division are often used by school children because the ÷ sign is what most people use when first learning division, and the short division format is usually the first algorithm learned for dividing arbitrary dividends, typically starting with the easier abbreviated short division form.

The expression on the third line, A/B, is the way division is usually written in software code. The four simple arithmetic operations in programming usually are +, -, *, /. This line was not in the first version of the comic. This is most commonly seen in regular mathematics as it

somewhat saves space, and is easy to type with the slash key. Additionally, it uses standard ASCII characters instead of sophisticated notation. A notable exception is APL, which uses an idiosyncratic character set modeled after traditional arithmetic.

The expression on the fourth line, A/B, is how division is usually written by hand.[actual citation needed] It is nearly identical to the fraction notation that follows, but the diagonal line allows each number to be bigger while still fitting into a single line of text. The third line's representation is the best approximation of this line's notation on a computer, without using more obscure Unicode characters. The Unicode character set can be used to accurately represent division as on the fourth line in plain text, using a small set of precomposed fractions (⅔, , etc.), regular numerals and U+2044 FRACTION SLASH (e.g. 22⁄7, provided font support exists), or superscript and subscript numerals (e.g. $^{22}/_7$, or $^{22}\!\!/_7$ with the fraction slash). Using any of these requires a greater knowledge of Unicode, and the know-how (and, possibly, patience) to type them, so it is likely that only a Unicode enthusiast would type division like this, rather than an alternate or equivalent format such as 22/7 as rendered in HTML.

The sixth, "fancy," notation uses a negative exponent. The exponent -1 is equivalent to reciprocation. It can be used to keep an entire division expression on one line. Note that AB-1 is equal to A/B only if A and B are in a commutative ring (and B has an inverse). If A and B are, for example, matrices, AB-1 is not the same in general as

B-1A (and the notation A/B is never used in this case as it would be ambiguous). The AB-1 format is also often used to express physical units.

The final form of notation declares a function. The writer defines a new function, F, that takes in the parameters A and B, before listing out the function's definition (trailing off in increasingly smaller text). Defining things as functions is very normal for mathematics, but likely not very efficient at all to commonly do for the simple operation of division. Occasionally a highly formalized definition such as this could be a setup for an elaborate and extensive proof, hence Randall warns the reader they should escape while they still can. Integer division can be defined in terms of multiplicative inequalities and the remainder, or modulo ('%' in most programming languages) operator. This situation is likely to occur in many sorts of algebra, where one might have to define what "division" means for two elements of a mathematical object such as a group, ring, or magma. One example would be an object G, such that, for two elements A and B of G, "A divided by B" is defined as an element C such that CB=A, or alternatively as an element C such that BC=A. These definitions will differ if multiplication in G is not commutative. Furthermore, if such a C is not unique, the function F(A,B) will need to include a method to select a unique value for "A divided by B" for each A and B. Thus, the F(A,B) in the comic might not even refer to a uniquely defined operation, but simply to the property of a function F(A,B) that is a valid division operation on G,

given some definition of division. You were warned.

The title text is a Science Tip. It discusses how the division sign (÷) has fallen out of favor in most professional contexts (the ISO-80000 guidelines even specify the symbol "should not be used") yet has resisted all efforts to repurpose it as a new function. Specifically, it pokes fun at how similar the division sign is to a percent sign (%). A scientist might be really mad at the use of the division sign as an alternative to a percent sign because it is the wrong symbol in that context, even though they never use it for the original meaning anymore. The use of ÷ instead of % is something that may appear on signs for discount offers.

#2688: Bubble Universes

October 21, 2022

The theory finally unifies cosmic inflation and regular inflation.

Explanation

A bubble universe is a concept in the inflation theory of cosmology in which our observable universe is just one of many "bubbles" of matter and radiation that formed after the Big Bang.

The comic seems to be recursive, where one Cueball's bubble universe contains another Cueball doing the same thing, blowing bubbles, seeming to contain the whole scene within one of the bubbles in the original scene.

The title text claims this theory "finally unifies cosmic inflation and regular inflation." Cosmic inflation refers to the expansionary phase of the universe shortly after the Big Bang. Meanwhile, regular inflation refers to blowing bubbles, as this leads to them being inflated.[citation needed] This comic "unified" these theories with the simple proposition that the universe was a bubble and inflated like regular bubbles do. Unification of theories is a popular goal among scientists, since it makes it possible to provide a single explanation for multiple phenomena.

See also 2972: Helium Synthesis.

#2689: Fermat's First Theorem

October 24, 2022

$$A^N + B^N = C^N$$

SPELLS
ANT BACON

FERMAT'S *FIRST* THEOREM
WAS QUICKLY DISPROVED

Mathematicians quickly determined that it spells **ANT BNECN**, an unusual theoretical dish which was not successfully cooked until Andrew Wiles made it for breakfast in the 1990s.

Explanation

This is a reference to Fermat's Last Theorem, humorously implying that Pierre de Fermat created a similar theorem as a child. Fermat's Last Theorem states that no three positive integers a, b, and c satisfy the equation an+bn=cn for any integer value of n greater than 2. It is notable for having remained unproved for hundreds of years, despite many attempts to prove it; it's called his 'last' theorem because it was the last one left without proof or disproof. The Taniyama–Shimura conjecture (now known as the Modularity theorem) and the epsilon conjecture (now known as Ribet's theorem) together imply that Fermat's Last Theorem is true. The epsilon conjecture, proposed by Jean-Pierre Serre, became provable thanks to Ken Ribet in 1986. Andrew Wiles, with assistance from his former student Richard Taylor, succeeded in proving a special case of the Taniyama-Shimura conjecture for semistable elliptical curves in 1995, which finally established the proof of Fermat's Last Theorem. (The full Modularity theorem was subsequently established as correct by Wiles's former students Brian Conrad, Fred Diamond and Richard Taylor, and Christophe Breuil in 2001.)

The young Fermat here didn't try to prove the mathematical equation, but simply tried to read it as words, treating the "+" sign as a "t" so that "AN+" can be read as "ANT". His interpretation was quickly disproved because there's no "A" between "B" and "C", and no "O" between "C" and "N". It's unclear if this is considered

Fermat's First Theorem because it was the first he made, or because it was the first to be conclusively disproved.

In the title text, the "words" are "ANT BNECN", treating the equals sign "=" as an "E"; while "=" doesn't look especially close to "E", it is similar in that it contains horizontal bars in a horizontally symmetrical arrangement. The text then references Wiles, asserting that he proved this modified form of Fermat's First Theorem as well by cooking this "ant bnecn" (whatever "bnecn" is) as breakfast.

2492: Commonly Mispronounced Equations also contains equations pronounced as if they were words in the ordinary sense.

#2690: Cool S

October 26, 2022
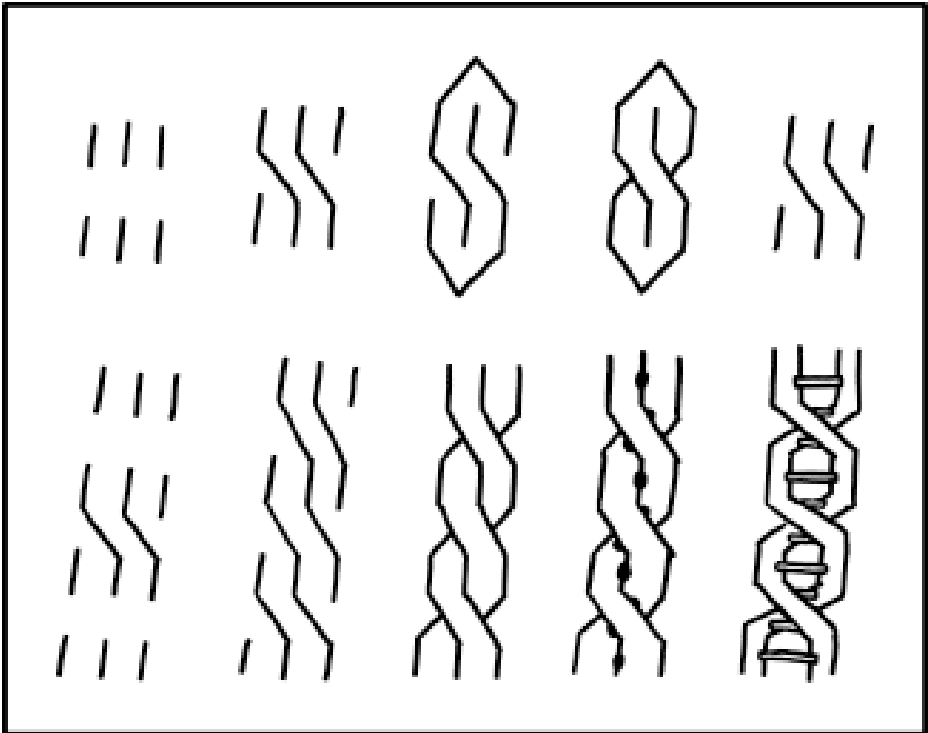
THE STRUCTURE OF DNA WAS ORIGINALLY DISCOVERED BY A GROUP OF ESPECIALLY COOL MIDDLE SCHOOL RESEARCHERS.

Although I hear they were caught cheating off of Rosalind, who sat at a desk in front of them.

Explanation

The 'Cool S' is a stylized drawing of the letter "S". It is a popular doodle among teenagers and pre-teens as it can be quickly hashed out using six vertical lines which are then connected with an appropriate pattern of diagonal lines. The drawing has been around for a very long time, and may be independently discovered simply because it is a logical progression of combining a series of straight lines in an interesting manner.

Randall first draws the steps to make the Cool S. Then he draws a chain of repeats of this pattern, excluding the end caps, making something that looks like a twisted rope. Finally he separates the two strands and adds cross bars, creating something that turns out to have a visual similarity to the discovered helical structure of DNA. However, although the final diagram is a double helix, the chirality, or "handedness", is backwards: an actual DNA molecule usually winds in the opposite direction (clockwise, if you're looking at it end-on). (The tutorial at How to (correctly) draw DNA describes this in more detail.) It is possible for left-handed DNA segments, called Z-DNA, to form in purine-pyrimidine alternating regions; but this is much less common than the more typical conformations of B-DNA and A-DNA. (B-DNA is the most common and is elongated with accentuated major grooves: see Nucleic acid structure. This asymmetry can be seen in the spacing between strand segments, which alternates between short and long distances, as opposed to A-DNA and Z-DNA where

these distances are much more uniform.)

He posits that the helical shape of DNA was originally discovered when somebody decided to doodle this extended S pattern.

Understanding the shape of the DNA molecule was an important step towards understanding how it duplicates itself and serves as a template for RNA. In real life, Francis Crick and James Watson were awarded a Nobel Prize for this discovery.
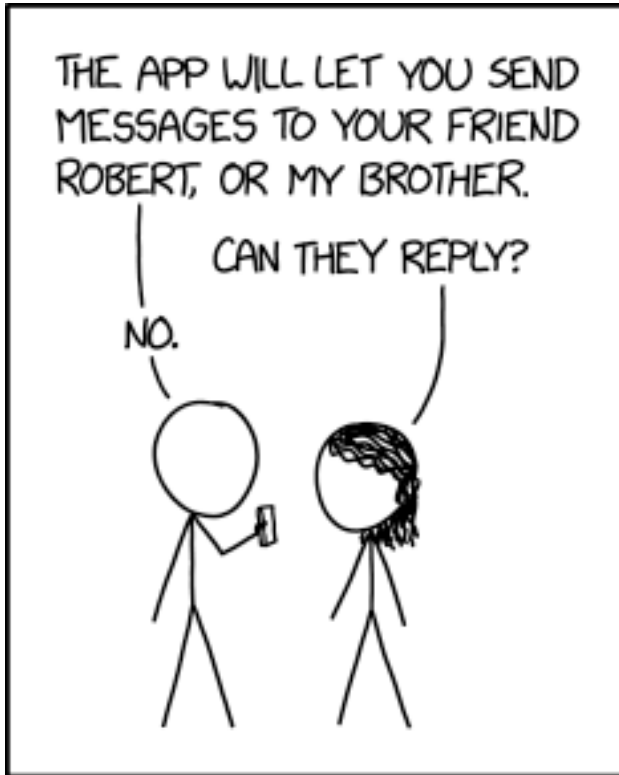
The title text is a reference to Rosalind Franklin, who made a material contribution to the discovery of DNA but was controversially not included in the Nobel Prize. Many are quick to assume she was excluded simply due to sexism, although she had also been dead for five years (Nobel rules now prohibit posthumous nominations (though this statute was not formally in effect until 1974)). Franklin's boss at the time of the discovery, Maurice Wilkins, was also named on the prize, and Nobel rules also forbid splitting of Prizes more than three ways. Wilkins had shared some of Franklin's data with Watson, who then shared what he saw with Crick. None of the three men ever told Franklin that Watson and Crick had based their model on her data.

This account is reminiscent of how August Kekulé said he identified the ring structure of the benzene molecule. He claimed to have had a dream in which the atoms were moving around, with the last grabbing onto the first like the classic image of a snake grabbing its tail, forming a

ring of six lines.

#2691: Encryption

October 28, 2022

THE APP WILL LET YOU SEND MESSAGES TO YOUR FRIEND ROBERT, OR MY BROTHER.

CAN THEY REPLY?

NO.

MY NEW SECURE TEXTING APP ONLY ALLOWS PEOPLE NAMED ALICE TO SEND MESSAGES TO PEOPLE NAMED BOB.

WARNING: PEOPLE NAMED EVE ARE PROHIBITED FROM INSTALLING THIS APP!

Explanation

When teaching encryption / cryptography, it is common to use a story about sending messages from Alice to Bob (Party "A" and Party "B" respectively). Cueball claims to have created a texting app that only allows for this one thing. It does not, however, allow "Bob" to reply, making the usefulness of the app questionable at best. It is unclear how it enforces the name restriction, but it is possible that the app figures out the name of the phone's owner. The title text mentions Eve, who in the typical story represents an "eavesdropper", someone who attempts to intercept the messages between Alice and Bob. The fact that persons named Eve are 'forbidden' from installing the app suggests that it might not actually be as secure as Cueball advertises -- it may be that he naively thinks that it's just the name that makes the eavesdropper, and that by excluding all Eves, Alice's messages to Bob will remain private. It is not clear which phones will support this app, but it appears to be perfectly suited for the xkcd Phones.

The comics 177: Alice and Bob and 1323: Protocol are also about Alice and Bob.

Even if the assumption that you could divine people's roles and motives from their names were correct, if the names of the users don't need to be verified, it seems possible for a bad actor to circumvent the security features of the app by simply lying about their name. Genuine users could also undermine the security with
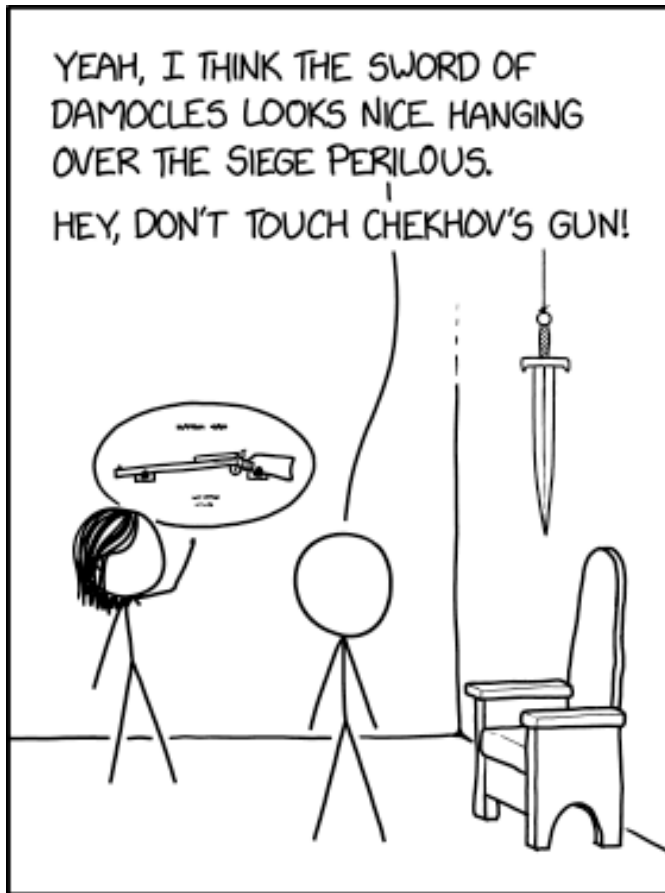
double installations and a complete mess of a contact list in which everyone's names are somehow identified as "Alice" or "Bob", in order to increase its utility to them. Also, it would appear that "Bob" needn't be the commonly used name of the message receiver, in this scenario – it could also be a diminutive of what he is actually known by. Thus a user might claim to be "Bob" whichever his given name is.

This may be related to the announcement that Signal would be discontinuing support for SMS/MMS messages.

#2692: Interior Decorating

October 31, 2022

YEAH, I THINK THE SWORD OF DAMOCLES LOOKS NICE HANGING OVER THE SIEGE PERILOUS.

HEY, DON'T TOUCH CHEKHOV'S GUN!

MY HOME DECORATING THEME IS "OMINOUS METAPHORICAL OBJECTS."

It all came flat-packed in Pandora's Box.

Explanation

The sword of Damocles, Siege Perilous, Chekhov's gun, and Pandora's box are mythical or conceptual objects associated with impending threats. These names are now used metaphorically for complex concepts related to danger. Cueball seems to have either taken inspiration from these tales and named some objects after them or (possibly with Beret Guy's help) managed to obtain the genuine items, using them as decorations in his house.

The Sword of Damocles refers to a lost history of Sicily, in which Damocles was said to be an obsequious courtier who envied the king's power and luxury. The king offered to let Damocles serve as king for a day, but during that day, arranged for a sword to be hung above the throne, suspended by a single hair. This was to teach Damocles the lesson that, along with the privileges of being king, there was also perpetual and inescapable danger and anxiety. The term has passed into general use for any situation that involves an ever-present threat of harm.

The Siege Perilous, in Arthurian legend, is a seat at the Round Table, reserved by Merlin for the knight destined to retrieve the Holy Grail. It was said to be fatal to any unworthy person who sat in it. The term is used as a metaphor for any situation that's exceptionally dangerous to anyone not fully prepared.

Chekhov's Gun is a writing principle highlighting the

importance of conservation of detail. The term originates from playwright Anton Chekhov, who repeatedly used the example of an unfired gun to advocate removing superfluous elements from a narrative. In one such case, he said "If in the first act you have hung a pistol on the wall, then in the following one it should be fired. Otherwise don't put it there." (It should be noted that, like most artistic rules, experienced writers will deliberately violate this advice when appropriate, especially to creatively misdirect similarly experienced audiences.) Cueball might not want Megan touching it because doing so means it will be fired shortly afterwards, following through its core concept.

Pandora's Box is a tale from Greek Mythology. According to myth, Pandora was the first woman, created by Hephaestus, and was given a jar (later translated as "box") and told never to open it. Eventually she did, and unleashed all the miseries into the world. The term has come to represent any situation where a small but ill-considered action results in numerous, often intractable, problems.

Given that two of the objects are potential hazards (the sword and the gun) and the third explicitly fatal, it is quite apt that they would come in such a box.

#2693: Wirecutter Recommendation

November 02, 2022
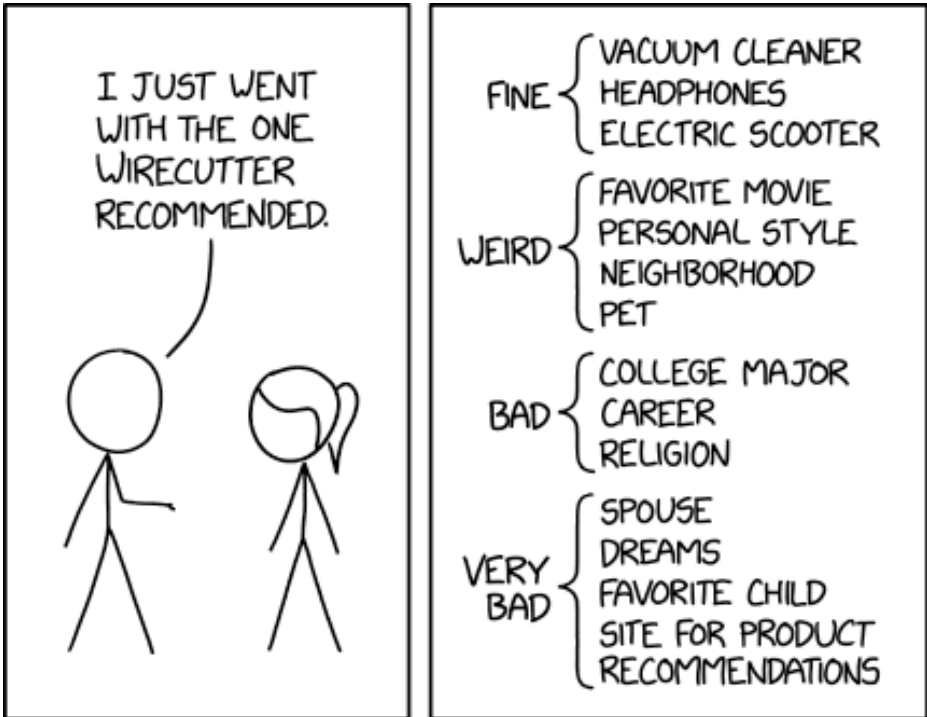
Their 'best philosophy of epistemology' picks are great, but you can tell they're struggling a little in the 'why you should trust us' section.

Explanation

Wirecutter is a product review website, owned by The New York Times. As such, Wirecutter is best used for comparing brands and models of consumer products. The comic, however, lists things that Wirecutter should not recommend, or that one should not choose based on Wirecutter reviews.

The first panel shows Cueball telling Ponytail that he decided to go with Wirecutter's recommendation when buying something unspecified. The second panel shows a list of different contexts for this conversation, ranking them from "Fine" to "Very Bad".

The title text references epistemology, a branch of philosophy concerned with the nature of knowledge and truth, for which Randall says Wirecutter's recommendations are great. Broadly speaking, epistemology attempts to answer the question "how do I know that what I know is true?", a very similar question to 'why you should trust us', which ironically the Wirecutter staff struggles to answer despite (or perhaps because of) ostensibly having picked the best philosophies of epistemology.

#2694: Königsberg

November 04, 2022
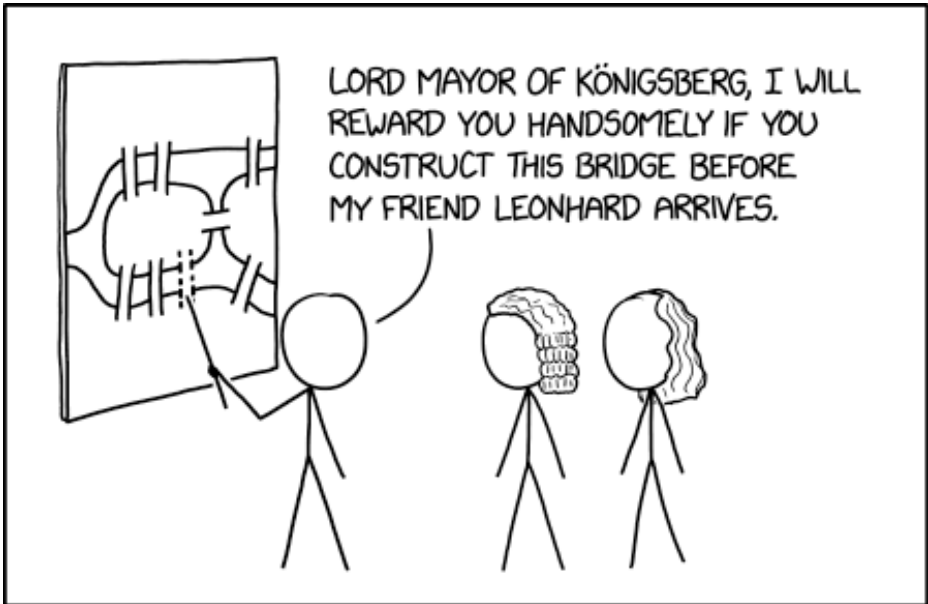
I TRIED TO USE A TIME MACHINE TO CHEAT ON MY ALGORITHMS FINAL BY PREVENTING GRAPH THEORY FROM BEING INVENTED.

At first I thought I would need some gold or something to pay him, but then I realized that it was the 18th century and I could just bring a roll of aluminum foil.

Explanation

This comic is about the Seven Bridges of Königsberg, a seminal graph theory problem solved by the famous mathematician Leonhard Euler. The problem was whether a path through the city crossing each of the seven bridges just once exists, without crossing the river forks any other way. In 1736, Euler proved that no such path exists. This result is considered to be the first theorem of graph theory and the first proof in the theory of networks — a subject now generally regarded as a branch of combinatorics — and presaged the development of topology. Combinatorial problems of other types had been considered since antiquity. Graphs are a data structure common in many algorithmic problems in computer science.

Cueball attempts to cheat on the final exam in his algorithms class by traveling back in time to commission the construction of an eighth bridge before Euler could learn of the problem, allowing a trivial solution that would remove the rationale for further analysis. He hopes that this would alter his present-day timeline in such a way that the test becomes easier because graph theory might never have been developed. The use of the word "tried" implies failure, which is probably a good thing since his success would create a paradox. Time travel is a recurring topic on xkcd and examples where attempts to change the past fails has also been used before like in 1063: Kill Hitler.

With the addition of the eighth bridge, it becomes possible to cross each bridge exactly once, starting at the north bank and ending on the larger eastern island, or vice-versa. However, there is still no way to traverse each bridge exactly once and return to the starting point, because the altered graph would have an Euler trail but not an Euler cycle. Thus the problem might still have been interesting to Euler.[citation needed] (Adding a ninth bridge connecting the north bank to the east island would render the problem completely trivial.) We can't say whether Euler or others would have developed graph theory anyway, or whether Cueball's exam would have been any easier or more difficult.

An alternative modification allowing an easy solution is to remove bridges. During World War II, two bridges to the central island connecting it to the north and south banks were destroyed by bombing, so today there is an Eulerian trail across the five remaining bridges.

The title text alludes to the fact that ordinary aluminum foil, which was not commercially available until 1911, would have been a tremendously valuable curiosity in the 18th century, which didn't even have tin foil (the inferior pre-World War Two version of aluminium foil, but the name still persisting to refer to its successor). Aluminum was a highly priced metal before the 1880s when inexpensive methods were developed to refine it. The Washington Monument was constructed with a tip made of pure aluminum due to its value and conductive capacity (this turned out to be a bad idea, because it attracted lightning, which melted some of the

aluminum). Aluminum had not been extracted in its pure form at the time of Euler, and was known only in compounds such as alum, so the metal would have been unique and exotic. The value of aluminum and the use of it as the tip of the Washington Monument was also mentioned in 1608: Hoverboard where a heist to steal the tip is depicted.

#2695: Soil

November 07, 2022
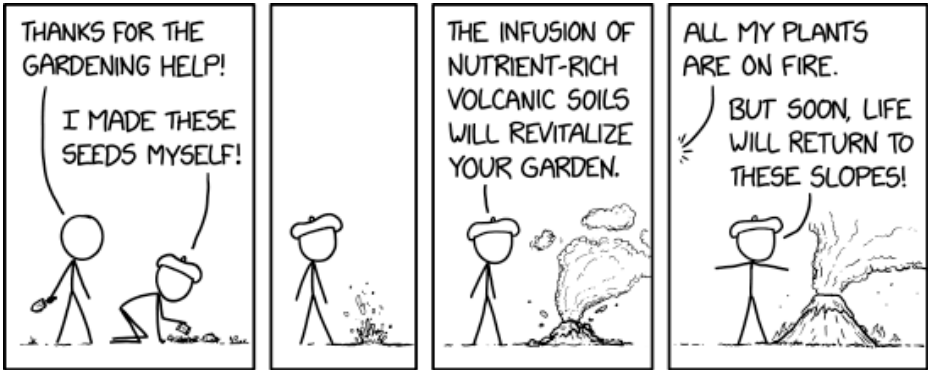
You might want to bring your frost-sensitive plants in from the patio. The high-level aerosols may result in short-term cooling across the entire backyard.

Explanation

Beret Guy seems to be using volcano seeds to grow a tiny volcano to fertilize Cueball's garden. In reality, volcanoes are caused by the pressure of magma (underground lava) from below the Earth's crust pushing up through it, not seeds.[citation needed]

In the first panel, Beret Guy states that he made these seeds himself, presumably using his proven skill at exotic bioengineering. It is unclear whether his volcano is capable of self-propagating but, until his 'help' with maintaining the garden, there would probably be no particular risk of volcanic activity.

Volcanic soil is generally fertile and replenishes depleted elements in the soil, just like commercial fertilizers. However, the process of eruption is destructive to whatever plants are presently in the garden, as Cueball points out. Beret Guy's announcement in the final panel resembles the voice-over from a nature documentary.

The title text alludes to the fact that sulfate aerosols from volcanic eruptions may cause a short-term cooling effect because the aerosols in the atmosphere block out energy from the sun. This expands on the comedy from a small scale volcano by adding small scale volcano effects. Realistically a small supply of aerosols would be blown away and dispersed by wind. Not to mention the fact that, of course, the currently flowing lava is potentially harmful to all plants near the garden anyway.

#2696: Precision vs Accuracy

November 09, 2022

	HIGH ACCURACY	MEDIUM ACCURACY	LOW ACCURACY
HIGH PRECISION	BARACK OBAMA WAS PRESIDENT FOR 70,128 HOURS	BARACK OBAMA WEIGHS AS MUCH AS 17.082 CATS	BARACK OBAMA IS 70.128 FEET TALL
MEDIUM PRECISION	MOST CATS HAVE 4 LEGS	BARACK OBAMA IS 6'1"	BARACK OBAMA HAS 4 LEGS
LOW PRECISION	MOST CATS HAVE LEGS	BARACK OBAMA HAS FEWER LEGS THAN YOUR CAT	BARACK OBAMA'S CAT HAS HUNDREDS OF LEGS

'Barack Obama is much less likely than the average cat to jump in and out of cardboard boxes for fun' is low precision, but I'm not sure about the accuracy.

Explanation

Accuracy and precision are common concepts to be encountered in the scientific field and often students have issues with the differences between them. Accuracy concerns whether a statement is true, while precision concerns how detailed it is; it is possible for a statement to be one but not the other. The comic explores this concept by comparing Barack Obama, former President of the United States, with cats. Confusingly, he measures different statistics of both Barack Obama and cats (sometimes measuring them in terms of cats) leaving the unwary reader even more confused.

Being precise is typical of calculations that roll out an excess of significant digits, often in the form of trailing decimals. Precision is lowered by using more rounded figures, or merely being comparative, but largely unaffected by whether the original values used were accurate or even correct. Accuracy is a cumulative function of the accuracy given to the intermediate values used for any calculation, and can be degraded by using figures that are themselves in some way inaccurate or imprecise. One part of confusion between the two is because being too precise usually decreases accuracy.

The numbers mentioned in the top row (high precision) of the table all use exactly the same digits, dictating that a full five digits of precision are used in them all. The most "valid" or correct value is a number that's very accurate and precise (see table). For the medium accuracy the

number is an anagram of the 1st entry, giving a value that is reasonable but would be overly exact, whilst the low accuracy number is just a repeat of the first entry's digits with a shifted decimal but clearly at the wrong scale, as Randall could have shifted the decimal point one further place to the left to be closest to the true measurement. Instead, he replaces the thousands separator with the decimal point, perhaps for the visual pun.

The title text compares Obama's and cats' enjoyment of playing with cardboard boxes. While cats are known to do this,[citation needed] we don't know whether Obama does.

The day prior to the publication of this comic (November 8, 2022) was election day in the United States, so Randall may have been remembering Barack Obama's presidency at this time.

#2697: Y2K and 2038

November 11, 2022

2000   2019   NOW ▼   2038

RECOVERING FROM THE Y2K BUG | PREPARING FOR THE 2038 BUG
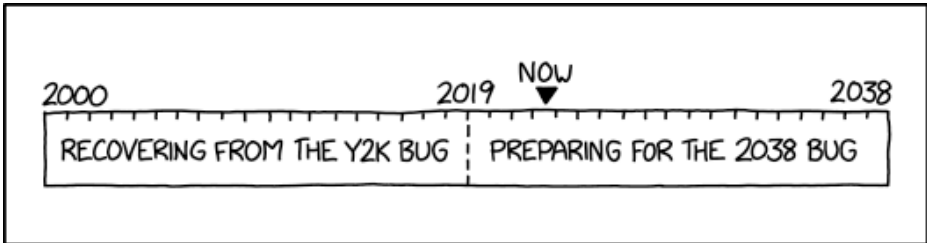
REMINDER: BY NOW YOU SHOULD HAVE FINISHED YOUR Y2K RECOVERY AND BE SEVERAL YEARS INTO 2038 PREPARATION.

It's taken me 20 years, but I've finally finished rebuilding all my software to use 33-bit signed ints.

Explanation

The Y2K bug, or more formally, the year 2000 problem, was the computer errors caused by two digit software representations of calendar years incorrectly handling the year 2000, such as by treating it as 1900 or 19100. The year 2038 problem is a similar issue with timestamps in Unix time format, which will overflow their signed 32-bit binary representation on January 19, 2038.

While initial estimates were that the Y2K problem would require about half a trillion dollars to address, there was widespread recognition of its potential severity several years in advance. Concerted efforts among organizations including computer and software manufacturers and their corporate and government users reflected unprecedented cooperation, testing, and enhancement of affected systems costing substantially less than the early estimates. On New Year's Day 2000, few major errors actually occurred. Those that did usually did not disrupt essential processes or cause serious problems, and the few of them that did were usually addressed in days to weeks. The software code reviews involved allowed correcting other errors and providing various enhancements which often made up at least in part for the cost of correcting the date bug.

It is unclear whether the 2038 problem will be addressed as effectively in time, but documented experience with the Y2K bug and increased software modularity and access to source code has allowed many otherwise

vulnerable systems to already upgrade to wider timestamp and date formats, so there is reason to believe that it may be even less consequential and expensive. The 2038 problem has been previously mentioned in 607: 2038 and 887: Future Timeline.

This comic assumes that the 38 years between Y2K and Y2038 should be split evenly between recovering from Y2K and preparing for Y2038. That would put the split point in 2019. The caption points out that it's now, in 2022, well past that demarcation line, so everyone should have completed their "Y2K recovery" and begun preparing for year 2038. It is highly unlikely that there are more than a very few consequential older systems that still suffer from the Y2K bug, as systems built to operate this millennium handle years after 1999 correctly. The topic of whether or not Y2K was actually as big of a problem as it was made out to be remains hotly debated. The main arguments falling into the general camps of "nothing bad happened, Y2K would have overwhelmingly been an inconvenience rather than a problem" vs. "very little happened only because of the massive effort put into prevention". It is unlikely that there will ever be a conclusive answer to the question, with the truth probably being somewhere in between those two extremes. Whatever the answer to that question may be, the reaction to Y2K did result in a significant push towards, and raise in public awareness of, clean and futureproofed code.

The title text refers to replacing the 32-bit signed Unix time format with a hypothetical new 33-bit signed

integer time and date format, which is very unlikely as almost all contemporary computer data structure formats are allocated no more finely than in 8-bit bytes. Doing this may seem complicated to new software developers, but recompiling with a larger size of integers was a normal solution for the Y2K bug among engineers of Randall's generation, who learned to code when computer memory space was still at a premium. For example, in most implementations of the C language, the data type that represents 32-bit integers is called "long", while a 16-bit integer is a "short". C actually does allow programmers to declare a 33-bit integer ("long long:33"), but they're really just treated as 64-bit numbers that get truncated when stored, and would be slow unless running on custom hardware that supports such a type natively (which no hardware currently does). Taking 20 years to develop and implement such a format is not entirely counterproductive, as it would add another 68 years of capability, but it is a far less efficient use of resources than upgrading to the widely available and supported 64-bit Unix time replacement format and software compatibility libraries.

#2698: Bad Date

November 14, 2022
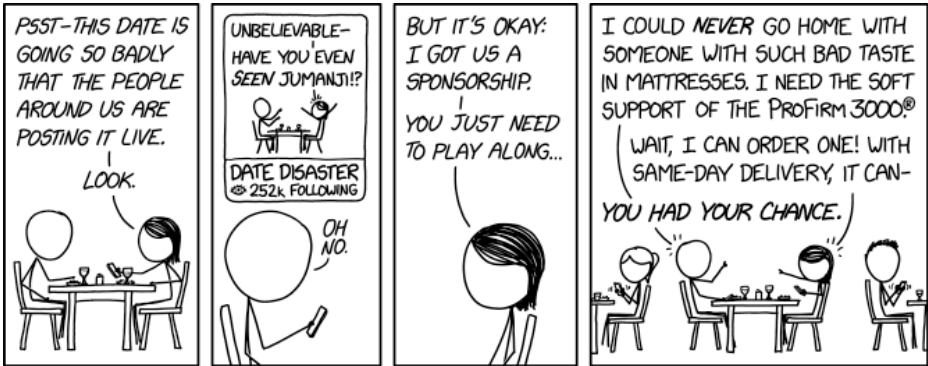
"Even split between us, this will pay way better than the Jumanji sponsorship I came into the date with."

Explanation

This comic is a spoof of Internet influencers. These are people with large social media followings who mention products in their videos in exchange for payment from the companies that produce these products, as a form of advertising.

In the comic, Megan and Cueball are not intentionally live-streaming their date, but someone around them is uploading video footage of their date, because they were having an argument about the movie Jumanji. Megan realized that they can capitalize on this by getting a sponsor.

The argument then shifts to whether they're going to sleep together after the date. Cueball says he won't go home with Megan because she doesn't have the mattress brand sold by their sponsor. She responds by pointing out a feature of that brand: their same-day delivery policy. This argument could easily be a TV commercial for the mattress, though Cueball's ultimate retort suggests (whether he wants it to or not) that there still won't be a "happy ending" conclusion to this play-acting, either fictionally or once real life resumes.

The title text hints, however, that Megan was already before the date going to promote the Jumanji franchise, for her own gain. Megan's realization that she could not discuss this subject since Cueball had not seen it leads to her initial reaction starting their date to be shared, but

not for the reason she had anticipated. But then when she sees they are still going viral, she is ready to use this new situation to bring in a lot of "mattress money". And as it turns out even when splitting with Cueball she will earn more. Since Cueball presumably came into the date with the intention of finding a romantic partner rather than gaining a sponsorship, he will probably get even less happy with Megan. Alternatively, as he plays along with her in the last frame, he sees this as an acceptable or even preferable arrangement (considering that the date wasn't going all too well in the first place).

#2699: Feature Comparison

November 16, 2022

	Twitter	Discord	Mastodon	FB	Slack	Signal	IRC	Tumblr	Reddit	SMS	CYBIKO® WIRELESS HANDHELD COMPUTER FOR TEENS (2000)
DIRECT MESSAGES	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GROUP CHATS	✓	✓	✓	✓	✓	✓	✓		✓		✓
FILE TRANSFER		✓	✓	✓	✓	✓	✓				✓
BUILT-IN GAMES		✓		✓							✓
USER-RUN INSTANCES		✓	✓		✓		✓		✓		✓
DOESN'T REQUIRE CENTRAL SERVER			✓				✓				✓
MESH NETWORKING											✓
WIRELESS MESSAGE DELIVERY WORKS WITHOUT INTERNET										✓	✓

Below the Web, and the Dark Web, a shadowy parallel world of Cybiko users trade messages on the Translucent Neon Plastic Web.

Explanation

This comic compares different remote communication services, including the relatively well-known Twitter, Discord, Mastodon, Facebook (FB), Slack, Signal, Internet Relay Chat (IRC), Tumblr, Reddit, and SMS mobile telephone text messages. It also includes the less well-known Cybiko® wireless handheld computer for teens. For each of these, it purports to indicate which of various features they support. The comic illustrates how feature comparison charts and infographics can be abused by sellers who are trying to make their products look better than they really are, compared to their competitors. The comic may have been inspired by the recent surge in users looking for an alternative to Twitter, due to its purchase by Elon Musk, and the subsequent mass firings and resignation of its staff.

The Cybiko was a handheld computer designed for teens and released in 2000, which featured its own two-way radio text messaging capabilities along with built-in games and a music player. Additional information about it is available at the Dead Media Archive, as the device has not been manufactured since 2003. The chart suggests that the Cybiko has an advantage over all of the other listed communication services, as it is capable of all eight of the table's listed features, with none of the others being close.

The features compared are direct messaging, group chats, file transfer, built-in games, instances of the software run

by individual users instead of the corporation producing it, lack of a central server requirement, mesh networking, and wireless message delivery without an active internet connection.

Mesh networking is a form of connectivity that reduces or removes the need for a centralized server or predefined gateways to a communications 'backbone'. Nodes communicate directly with any nodes that happen to be contactable, and from there may connect through to whatever nodes are in mutual contact, or to be found further afield, either in real-time or asynchronously. The Cybiko has this ability, as well as wireless message delivery because it communicates directly to other devices via radio, hence the ability to operate without any internet connectivity at all. There are several ongoing projects for distributed social networking, but all of these additionally require a hardware layer to provide signalling via their respective protocols. The Cybiko provides such via its decentralized radio capabilities.

The comic does not mention the downsides of the Cybiko, that being purchasing one, and finding friends who own one, can be its own challenge, as it was discontinued nearly 20 years ago. Additionally, the comparison can be considered apples to oranges, since Cybiko is a device rather than a service; a fairer comparison would be to a modern smartphone, which can provide most of these features via multiple apps, including ones written especially for such rival services. Even ignoring the above, some of the Cybiko's "advantages" come with their own drawbacks: while not

requiring a central server nor the Internet, for example, is touted as a plus, the Cybiko instead relies on having other devices in proximity to relay messages, meaning that unless the person you are sending to is nearby, it will not function. This is not an issue on any of the other options.

This comic contains several errors. Mastodon doesn't support file transfer. Discord does not provide for user-run instances itself, only user-moderated and administrated instances. (There are two third party Discord server implementations, but it is unclear whether those could be counted as run by users.) Slack does not provide for user-run instances itself. Reddit does not provide for user-run instances at all, only user moderation and administration. IRC does require at least one central server, and relegates file transfer support to client extensions. Signal is heavily used in user-run instances via a diverse ecosystem of code forks; many of these don't require a central server, a couple use mesh networking. Reddit occasionally does have built-in games. Finally, SMS has a form of group chats, (Tumblr used to have a form of group chat, but it was removed in September of 2021).

The comic has been updated twice to fix some of these errors. The first version suggested Mastodon did not support user-run instances and required a central server, and that Reddit supported file transfer. This was changed once shortly after publication to add a check mark under "Mastodon" for "User-Run Instances". A second change was made some time later to check

"Doesn't Require Central Server" for Mastodon and uncheck "File Transfer" for Reddit.

The title text refers to the translucent plastic covers that were popular in the late 1990s and early 2000s.

#2700: Account Problems

November 18, 2022

My password is just every Unicode codepoint concatenated into a single UTF-8 string.

Explanation

Cueball asks Ponytail to help him because he can't log in to his account. Having attempted to fix Cueball's tech issues in the past, Ponytail replies with dread. Cueball promises that "It's a normal problem this time", and Ponytail agrees to look at it. But then Cueball reveals that he has included a null string terminator character in his password when creating an account and now he can't log in.

In computer systems, every "character" (letter, digit, punctuation, etc.) is represented as an integer. For example the lowercase letter 'a' is represented as the number 97, and the digit '1' is represented as the number 49 (when using the ASCII character encoding or Unicode character encoding). A "string" refers to a sequence of characters, and can be used to store arbitrary text (for example names, messages, passwords). Strings can be arbitrarily long, so some mechanism must be used to record their length. One approach is to store the length explicitly (Pascal string). Another approach is to mark the end of the string using a specific character, usually the null character (which is represented as the number 0); such strings are called null-terminated strings, and are used by the C programming language. Both approaches have advantages and disadvantages. A limitation of null-terminated strings is that they cannot be used to represent text containing embedded null characters. This is usually not a problem, because normal text never contains null characters. However, if somehow

a null character were to end up in the string, it would cause problems: any code that uses that string would assume this null character marks the end of the string, so the string would effectively be cut off.

Account registration systems often place requirements on passwords in an attempt to encourage users to pick stronger passwords. For example, they might ask that the password include at least one "special character" (such as !@#$%^&*). Cueball misunderstood this requirement as referring to characters such as the null character (which is more accurately referred to as a control character). Cueball managed to type the null character as part of his password somehow (on some systems it is possible to type the null character using certain keyboard shortcuts such as Ctrl+Space, Ctrl+@, Ctrl+2, or Alt+0 using the number pad), but the software running the registration system was poorly written and could not cope with this – it allowed him to create an account with that password, but then when he tried to log in with the same password the system didn't accept it.
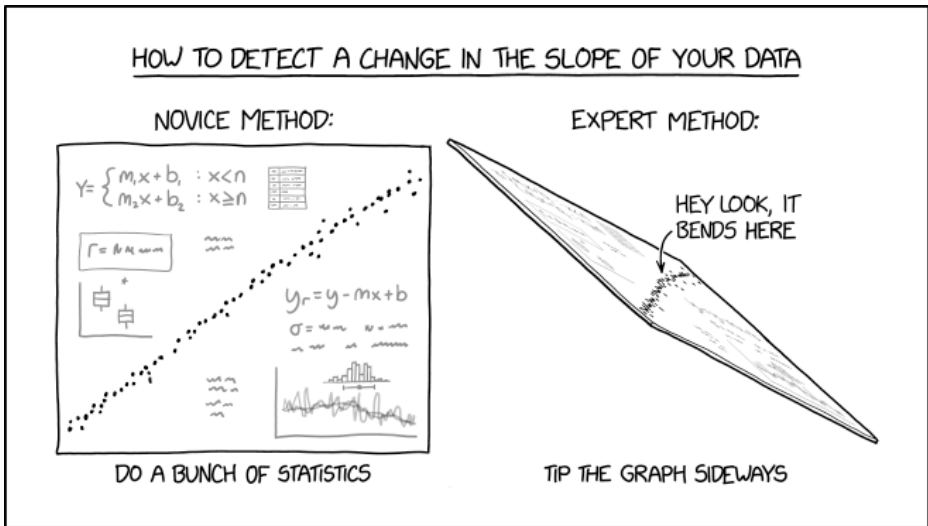
It's unclear how that particular situation might arise in real software, but here is a similar situation that can easily happen in practice: Suppose a website's registration form allows the user's new password to have up to 20 characters, but due to a programmer error the login page only accepts passwords with up to 18 characters. If the user picks a medium-length password (say with 12 characters), all is well. But if the user picks a password with 20 characters, they will find themselves in the same position as Cueball, being able to register but not able to

log in. Some additional situations are described below.

The title text describes a password which is "just" every Unicode character concatenated into a single string. Unicode is a standard for representing characters from many writing systems, and it has 149,186 characters as at the time of this comic (with new characters being added over time). A password consisting of all of those characters would be extremely long; it would be impractical to type by hand, and would be too long for pretty much all account registration systems. (A "codepoint" is the number assigned to a character, and UTF-8 is a common encoding system for representing each Unicode codepoint as a sequence of bytes.) Also, since Unicode includes the null character, the password would have the same issue as Cueball's password. Further, if the account registration system treats the null character as a string terminator (as in C), then the password would be equivalent to an empty password (assuming it contains the Unicode codepoints in order, starting with the null character).

#2701: Change in Slope

November 21, 2022

HOW TO DETECT A CHANGE IN THE SLOPE OF YOUR DATA

NOVICE METHOD:

$Y = \begin{cases} m_1 x + b_1 & : x < n \\ m_2 x + b_2 & : x \geq n \end{cases}$

$r = $

$y_r = y - mx + b$

$\sigma = $

DO A BUNCH OF STATISTICS

EXPERT METHOD:

HEY LOOK, IT BENDS HERE

TIP THE GRAPH SIDEWAYS

Squinting at a graph is fine for getting a rough idea of the answer, but if you want to pretend to know it exactly, you need statistics.

Explanation

The comic is a tip for detecting changes in slopes over a scatter plot of data. This is a common requirement in exploratory statistics for comparing trends in a series — finding the cutoff where the slope changes may reveal valuable information about the data.

The comic compares two methods. Firstly, a novice method — by 'doing a bunch of statistics'- i.e, applying various statistical tools to analyze the data and figure out the quantitative change in slope. This results in two equations for the trendlines above and below a given value, a box plot, a histogram, and a line chart. It is unknown exactly what methods the novice used to figure out the change in slope in the data. Possibilities include calculating the derivatives (which probably won't work well on noisy data such as shown), or gradients, or using a Savitzky-Golay filter or piecewise linear smoothing spline fits. Randall's light gray figures may be suggesting this method.

The other is the so-called 'expert' method, which involves tilting the page the graph is printed on to view changes in slope better. For small changes in an underlying trend, similar to that apparently shown in the comic, direct visual inspection cannot always identify or even reveal the effect. The comic shows, however, that by taking the page and rotating it in just the right way, the foreshortened perspective can make certain details much more apparent, allowing the 'expert' to see at a glance

that there is a change in the slope. Ironically, tilting the comic to make the original roughly resemble the perspective of the 'tilted' version graph shown in the comic shows that the right-hand panel is slightly exaggerated for visual effect. The use of perspective to make information pop into the audience's view has been used by artists for centuries.

However, applying such an approach to data plots can run into errors — the primary one being parallax error from the oblique viewing angle causing the observer to not necessarily identify or clearly find the point at which the slope changes. It also does not reveal any data about the quantitative value of the change in slope, merely proving the existence of one. Furthermore, noisy data might show an apparent slope change that is not representative of an actual change in the underlying data, so even more advanced statistics testing the hypothesis of whether an apparent slope change is real may likely be a good idea.

The title text then goes on to say that, while such a trick is useful to identify that there is some change in slope, in order to pretend to know it exactly one must revert to statistics (the "novice method") to obtain some form of information, defeating some of the premise of the comic. This at least produces a semblance of statistical rigor although, once an answer appears obvious, data could be interpreted to reach an answer that you are now expecting rather than revealing something of more statistically useful significance.

#2702: What If 2 Gift Guide

November 23, 2022

WHAT IF? 2 GIFT GUIDE

WHAT IF? 2 MAKES A GOOD GIFT FOR ANYONE WHO'S INTO SCIENCE, ABSURD IDEAS, OR JUST THE UNIVERSE IN GENERAL. TO ORDER, GO TO xkcd.com/whatif2, OR JUST TYPE "WHAT IF 2" INTO SOME RANDOM BOX ON YOUR DEVICE; IT WILL PROBABLY WORK.

HERE ARE SOME OTHER GIFT IDEAS FOR HARD-TO-SHOP-FOR SCIENCE ENTHUSIASTS:

INTEREST	GIFT IDEA
ENGINEERING	THE PLATINUM CYLINDER FORMERLY USED TO DEFINE THE KILOGRAM
BIOLOGY	THE GENOMES OF THE SCIENTISTS WHO HEADED THE HUMAN GENOME PROJECT
PHYSICS	A BEAM OF NEUTRINOS DELIVERED THROUGH THE EARTH BY THE LHC
ANIMALS	SURPRISE WILDLIFE ENCOUNTER (GIFT-WRAPPED BOX WITH A BOBCAT INSIDE)
LAW	A VACATION TO THAT AREA OF IDAHO WHERE YOU CAN COMMIT CRIMES WITH IMPUNITY DUE TO A COURT DISTRICT BOUNDARY ERROR
CHEMISTRY	A NECKLACE OF ELEMENT SAMPLES WHOSE SYMBOLS SPELL OUT THE RECIPIENT'S NAME. (NOTE: NAMES LIKE "KATHERINE" AND "BRANDON" MAY CAUSE RADIATION ACCIDENTS.)
PUZZLES	TWO GOATS AND A NEW CAR
TECHNOLOGY	CYBIKO® WIRELESS HANDHELD COMPUTER FOR TEENS (2000)
SPACE	WEBB TELESCOPE PERSONAL PHOTOSHOOT
LITERATURE	STEPHEN KING'S WRITING DESK (HE'S STILL USING IT SO YOU'LL HAVE TO FIGHT HIM)
PHILOSOPHY	OUT-OF-CONTROL TROLLEY
PSYCHOLOGY	A NICE GIFT WITH A NOTE SAYING YOU DON'T EXPECT ANYTHING IN RETURN

BABIES OR LITERATURE BUT NOT BOTH: Baby shoes

Explanation

Randall is again promoting his new book, What If? 2, and starts by explaining the kind of recipient who might appreciate it, basically anyone who is into science or anything in the universe... So basically anyone.

Then he also gives both direct and humorously indirect instructions of how to obtain the book for them, the latter method making a jocular (but not completely wrong) presumption that almost any text-input widget leads to some relevant search-engine result. Also the entire comic is a link to the What If? 2 page on xkcd that's included in the comic. As always, clicking anywhere on the image will take you there (including actually clicking on the link).

He also suggests some other tongue-in-cheek gift ideas for several other subtypes of gift-receiver, most of which are, in keeping with the What If ethos, somewhat dangerous or impractical. A number directly reference things previously mentioned or depicted by xkcd.

#2703: Paper Title

November 25, 2022
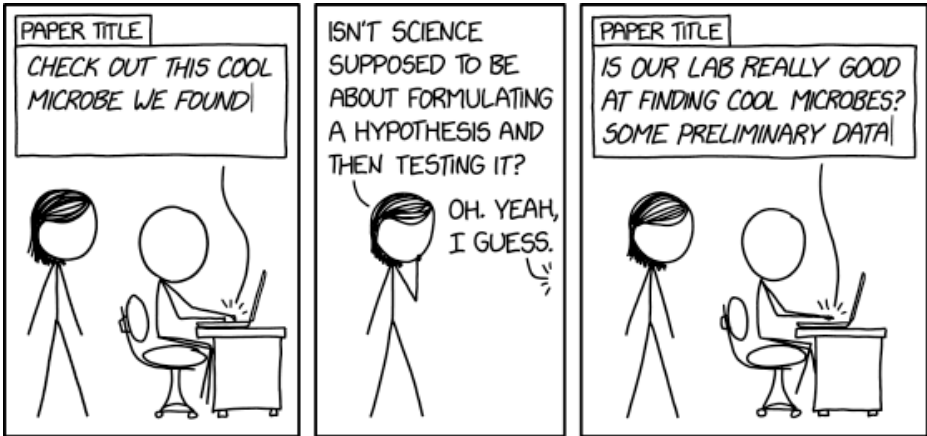
CONFLICT OF INTEREST STATEMENT: The authors hope these results are correct because we all want to be cool people who are good at science.

Explanation

Many if not most scientific research papers present a hypothesis and the result of testing the hypothesis. It is a common misconception that only that kind of research should be considered "science", but it is one of the key elements of the scientific method. Scientific papers should also have titles which describe the content of the papers, which may or may not reflect the full hypothesis in some abbreviated form. See also 2456: Types of Scientific Paper.

Cueball is writing a research paper with a clickbait, puffery and insufficiently descriptive title of "Check out this cool microbe we found." His colleague Megan asks him whether science is supposed to be about formulating a hypothesis and testing it. Cueball agrees, changing the title to "Is our lab really good at finding cool microbes? Some preliminary data." However, that is still an overly promotional and insufficiently descriptive clickbait title, purporting to be a study of the authors' own competence, which would be highly unusual because of the lack of objectivity due to the authors being the subject of investigation. Clickbait is a recurring theme on xkcd, recently considered within science publications in 2001: Clickbait-Corrected p-Value. The title of a research article describing a novel organism will often contain the author(s) proposed Linnaean name for it, which is granted as their prerogative within certain limitations.

Empirical investigations and analysis papers almost always state and test a hypothesis, but there are many kinds of scientific papers which usually do not, including literature reviews, which qualitatively summarize the results of other papers; meta-analyses, which quantitatively summarize the results and quality of other work; observational reports (or case studies — not to be confused with observational studies, a kind of empirical analysis), which present data and a chronicle of its collection often without analysis, testing, or interpretation; conference papers, which present preliminary work without peer review; definition papers, which attempt to formalize terms used in divergent ways in prior work; syntheses, which present alternative views combining multiple and often conflicting concepts; comparative studies, which compare and contrast a class of concepts; interpretive papers, showing a different perspective on previous work; technical reports, which may present information on a specific procedural topic or progress and results, if any, in a field; opinion and editorial essays, which are intended to argue a point of view persuasively; book reviews, which summarize monographs or biographies; and grant proposals, which make the case for funding a project. Mathematical or logic research papers which don't involve empirical observations or uncertainty would be considered technical reports in other fields. Engineering work can be reported as an empirical investigation or a technical report. Empirical research articles which do present and test a hypothesis are usually written in American Psychological Association (APA) style.

Cueball seems to want to author an observational report, but Megan would prefer an empirical investigation or analysis, perhaps because they may be more likely to be accepted by peer reviewed journals, and as such are more prestigious than mere conference papers, "letters" or "communications" as observational reports are often published. However, research articles describing the discovery of new microbes in prestigious peer-reviewed journals are often published as observational reports, so Megan's concerns may be unfounded; even if so, the editors of any reputable journal would almost certainly require a far more descriptive and less overtly promotional title from Cueball. The question remains whether an initial submission with a catchy clickbait title might get more prompt attention from editors and reviewers.

In the title text, a conflict of interest statement says that the authors hope their results are correct because "we all want to be cool people who are good at science." A scientific publication's potential conflict of interest usually refers to the authors' financial, familial, or other external interests in the research outcomes. The disclosure statement does not describe a conflict between the authors' extrinsic motivations and factors influencing the accuracy and neutrality of their work; in fact it claims the opposite, an alignment between their intrinsic motivations and the goal of producing high quality work, which should go without saying.[citation needed]

...SO YOU TIGHTEN THE SPIRAL TO MAKE THE WATER HOTTER, AND TO ADJUST THE FLOW RATE YOU JUST—

YOU NEED TO SLEEP.

NO! I CAN DO THIS!

EVERY DESIGNER'S DREAM IS TO FINALLY INVENT A NON-CONFUSING FAUCET CONTROL.

It's okay, they can figure out which control positions produce scalding water via a trial-and-error feedback loop with a barely-perceptible 10-second lag.

Explanation

A variety of faucet controls have been designed for the control of a shower or sink's water output; however, Randall seems to find all the existing options to be inadequate in some way and posits in this comic that designers share a desire to create a more ideal design. The comic shows one such designer, looking unkempt and rambling like a madman as he explains to an off-screen character how his new faucet design works. The off-screen character promptly tells him that he should get some sleep, a request which the designer ignores in favor of continuing the search for the "perfect" water faucet.

In general, a faucet's output has two independent parameters: flow velocity and temperature; some particularly frustrating faucet controls only offer one degree of freedom which simultaneously turns up the flow rate and the temperature, and thus cannot fully explore the shower-space (making it sometimes difficult to find a comfortable setting). Some faucets can adjust both parameters but only have a single lever which must be angled along degrees of freedom which are not always labeled clearly or intuitively, and this may also irk Randall. Other faucets have two independent controls for the flow of cold water and hot water; however, while these are highly granular, it can be difficult to adjust the parameters independently e.g. change the temperature without changing the flow, or changing the flow without changing the temperature.

While two-handle faucets may seem simple in the abstract, they are imperfect in practice. In older houses or those with hot water systems based on tankless or instant hot water heaters, the hot water pressure is rarely the same as the cold water pressure. This can cause problems with cold water flowing back into the hot line, creating temperature drifts, unexpected changes in temperature based on slight input changes, and non-reproducibility in shower settings.

Newer systems include thermostatic mixing valves which are designed to alleviate these problems; ideally, they contain one control for temperature and one for flow, which would seem to fit the "non-confusing" brief and solve Randall's problems. However, designing a system technically functional and making it intuitive (and making it work in practice for all water supply systems) is non-trivial, so Randall may have had trouble with even these faucets in the past.

The experience of a shower being affected by a significant change in usage of water elsewhere in the building (a running washing machine clicking into or out of a rinse-cycle, or the sudden use of a flush-toilet) is a typical one in any place without deliberately over-engineered plumbing. Purpose built hotels may have an in-built degree of resilience of this kind, but over many temporary stay-overs by guests (each new set having to become familiar with the plumbing) will develop wear and tear that later guests will not be automatically aware of — including the gradual wearing off of the traditional red and blue arrows intended to

show the polarity of hot-and-cold controls.

The title text is a hyperbolic and slightly sarcastic explanation of the merits of a faucet system, presumably from its designer. It describes that the user can identify an undesirable result, e.g. of scalding water, through a trial-and-error feedback loop. But, with a decidedly long delay in response time as the scalding (then non-scalding) mix works its way through the system, it means that they are left waiting for any adjustments made to prove themselves as useful (or not) whilst still experiencing the prior state of the water.

#2705: Spacetime Soccer

November 30, 2022
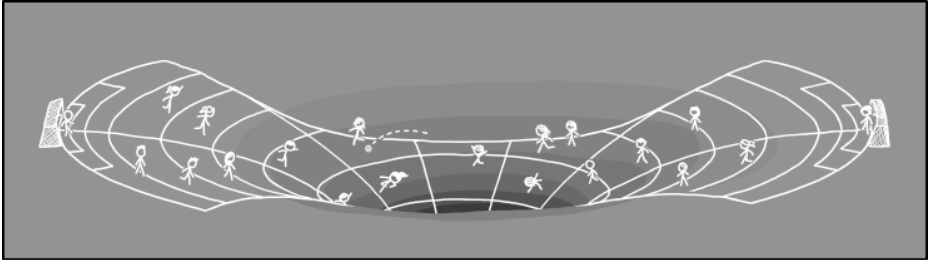
SPACETIME SOCCER GOT A LOT OF CRITICISM FOR HOW MANY PLAYERS
FELL INTO THE GRAVITY WELL, BUT WHAT ULTIMATELY DOOMED IT WAS THE
ADVANCED MATHEMATICS REQUIRED TO FIGURE OUT THE OFFSIDES RULE.

Spacetime Soccer, known outside the United States as '4D Football' is a now-defunct sport. Infamous for referee decisions hinging on inconsistent definitions of simultaneity, it is also known for the disappearance of many top players during... [more]

Explanation

This comic proposes Spacetime Soccer, a sport consisting of a "regular" soccer field with a gravitational well in the center of it. This comic was likely published in relation to the 2022 FIFA World Cup which, due to numerous controversies surrounding policies and conditions in the host country, Qatar, was prevalent in the 2022 news cycle for weeks.

Judging by the size of the blackest part of the indentation, presuming that indicates the event horizon of a black hole, the radius of its event horizon would be approximately 9.6 meters and the singularity's mass would be around $6.5×10^{27}$ kilograms, or more than 1082 times the mass of the Earth .

Not only would it be impossible for human players to travel through more than three spatial dimensions at will, it would also be very difficult to keep track of score and rules such as offsides.

Offside is a rule in soccer that applies to players who are in certain positions relative to the boundaries of the pitch, the ball and the second-last opponent on the opposing team. Players in such positions are eligible for being judged guilty of an offside offence if they become involved in the ongoing play before rectifying their status. It is of special importance to know the different players' positions at the exact moment the ball gets passed, rather than when the passed ball may be received

or the offside player is otherwise considered active. However, in relativistic spacetime, there is no universal definition of an exact moment beyond a single point, as time may run at different speeds for multiple observers in varying situations (where they are moving relative to each other, are influenced by differing local gravity or – as seems very likely in this example – both). An additional joke is that even in regular soccer, the offside rule is notoriously difficult to fully understand (or explain to someone).

The title text is written in the style of the beginning to a Wikipedia article on the topic. It alludes to the fact that most countries in the world refer to the sport with that particular obscure offside rule as football (or some translation thereof, like fútbol or Fußball) while the USA, Canada, Ireland, Japan and Australia all tend to call it soccer, which comes from the British shortening of "association football", because they already used the name "football" for gridiron football, Gaelic football or Australian football (which share a common ancestry, along with "rugby football", hence the name).

#2706: Bendy

December 02, 2022
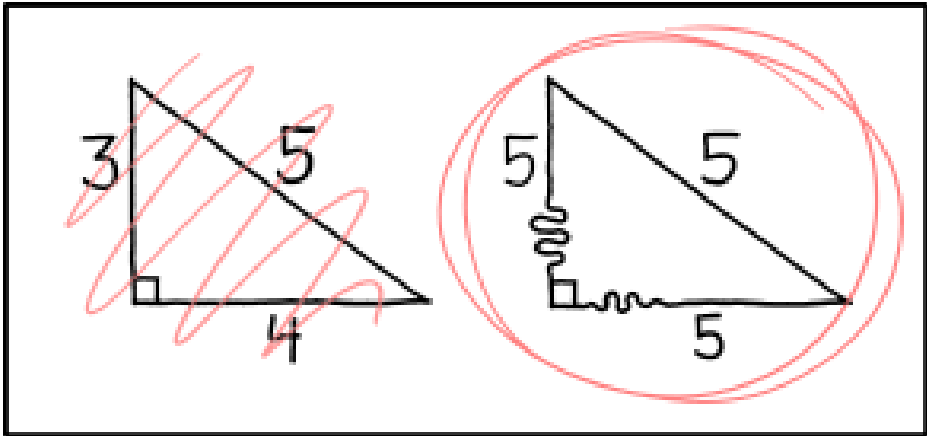
HUGE GEOMETRY BREAKTHROUGH: TURNS OUT THOSE LINES WE MAKE TRIANGLES OUT OF ARE BENDY!

Squaring the circle is really easy with some good clamps.

Explanation

Geometry usually represents 2D polygons with simple straight lines. In the comic, the lines are compared to a physical object, and are shown to have the property of bendiness. Randall claims this simplifies geometry as now triangles can have arbitrarily defined side lengths by merely stretching the lines, but it is unclear what benefits this may have over current Euclidean geometry. These lines cannot have Euclidean properties, but other non-Euclidean systems have been invented in the past with non-standard properties. One such non-Euclidean space can be modelled as the surface of a sphere. If the sphere had a circumference of 20, the triangle with three sides of length 5 would be right angled (at all three vertices).

This comic may be a reference to axis breaks in graphs, which shrink large segments and enhance readability and are denoted by a wiggly line on the axis in question, though this is more frequently done with angular zig-zags than the smoother curves as depicted.

The title-text talks about "Squaring the circle" (not to be confused with circle-squaring), a famous geometry problem based around constructing a square with the same area as a given circle, using a compass and straightedge, which was proven to be impossible (even with more powerful forms of construction, such as marked straightedges or origami) in 1882 as pi is a transcendental number. However, it then goes on to

describe a way to literally turn one of these bendy shapes from a circle into a square - namely using clamps.

#2707: Astronomy Numbers

December 05, 2022
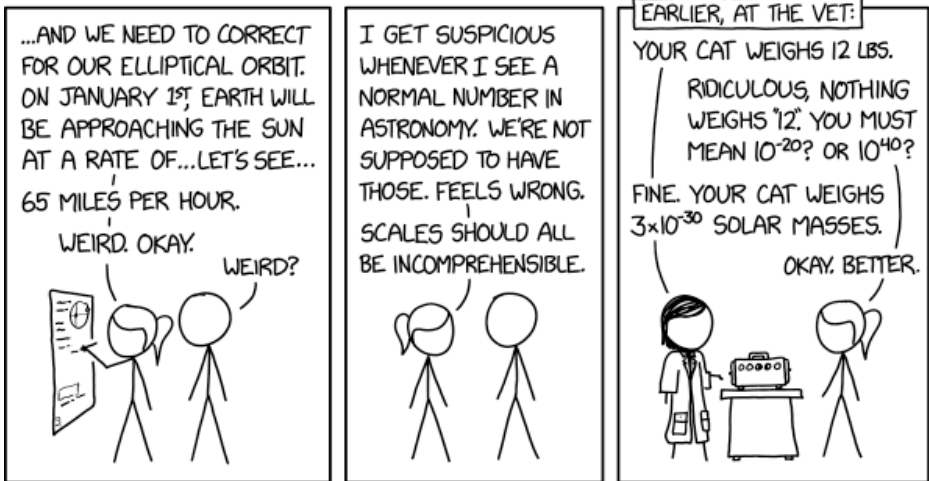
I adopted a cat that weighs 12 solar masses. Laser pointers love chasing it.

Explanation

Space is big, to the point that it regularly defies our earthly notions of scale. As a result, most quantities in astronomy have huge scales beyond anything that humans regularly experience or measure. (In fact, the word "astronomical" is sometimes used colloquially to describe any extremely large quantity).

For example, Earth has a mass 1023 times more than the average human, and the Sun is 105 times more than that, which itself is 1012 times less massive than the Milky Way. The same applies to speeds, distances, and time, which can often be measured in terms of light speed, light-years, and millions or billions of years. Because of this, it's a truly unusual occurrence for anything in space to end up in the fairly narrow range of scales of mass, size, speed, or time that humans can easily grasp.

Ponytail, apparently a scientist researching something related to Earth's orbit, finds that on a particular date, Earth will be approaching the sun at a velocity of 65 miles per hour. To American ears, this is a very normal sounding value (i.e. the speed of a fast-moving vehicle, often used as a speed limit on highways in the US). As Ponytail is accustomed to astronomical values, she is thrown off by this, and remarks that she finds it "suspicious" when reasonably human-scaled numbers come up in astronomy.

However, Ponytail seems to take this philosophy to an

absurd degree by insisting that all scales should be as incomprehensible as astronomical ones, even those used for human-scale measurements, such as the weight of cats. In the third panel, the vet, Megan, is seemingly used to this problem (perhaps she gets a lot of astronomers, or Ponytail has a hypochondriac cat), so she restates the 12-lb weight of Ponytail's cat in solar masses. Since using this unit yields an incredibly small number, 3×10^{-30} (a three preceded by a decimal point and 29 zeroes), it satisfies Ponytail's need for incomprehensibly-scaled values. This weight is in fact about 13 lb 2 oz (about 5.5 kilograms), slightly heavier than the initial figure given for the cat, but within rounding error for the single digit of precision that Megan uses.

The Earth's orbital velocity around the Sun is far above normal human scales (around 30 kilometers per second or 108,000 kilometers per hour). However, Earth has a fairly circular orbit around the Sun, so most of this speed ends up being tangential (sideways) rather than radial (towards or away from) the Sun, which is the value relevant for Ponytail's calculations. On January 1 (the date being discussed in the comic), Earth's radial velocity is close to its smallest value because we reach our closest point to the Sun in the first few days of January each year (in 2023, perihelion happens on January 4). Thus, by January 1, the Earth's velocity toward the Sun is nearly zero before it starts traveling away from the Sun again. This is how Ponytail ended up with the "suspiciously" small value of 65 miles per hour.

On the other hand, by April 3, 2023, Earth will be

receding from the Sun by almost 500 meters per second or 1800 kilometers per hour, which is a less normal speed for the average person to encounter in everyday life[citation needed].

65 miles per hour is approximately equal to 105 kilometers per hour, although the even more typical scientific value (in SI derived units) would be 29 meters per second.

The title text makes a joke by reversing the typical cat behavior of chasing laser pointer dots by envisioning a cat with a mass equivalent to 12 solar masses. The Schwarzschild radius for an object of that mass would be around 36 kilometers, so a cat-sized object of that mass would be a black hole, and would therefore bend all nearby light (including that from the laser) inwards towards its singularity. But then it should also draw in the physical laser pointer device itself, if it is neither very far away nor in orbit. And also the one holding the laser pointer, their house, and pretty much everything else on Earth.

#2708: Mystery Asterisk Destination
December 07, 2022

* WHENEVER YOU SEE A MYSTERY
ASTERISK THAT DOESN'T HAVE A
MATCHING FOOTNOTE, IT POINTS HERE.

If you ever see the dagger symbol with no unmatched footnote, it means the writer is saying the phrase while threatening you with a dagger.

Explanation

This comic pertains to the use of asterisks and other symbols for footnotes or endnotes.* It jokes that when an asterisk appears after a word without a corresponding footnote, it refers to this comic.* Missing footnotes can be frustrating, so this comic may provide closure for some readers; similar in spirit to 391: Anti-Mindvirus and opposite to the tension created by the unmatched parenthesis in 859: (.

The title text jokes that unmatched instances of † (the dagger symbol, also used for footnotes) are threats being made by the author to the reader with a physical dagger. As of this writing, it states "If you ever see the † dagger symbol with no unmatched footnote...", forming a double negative. This is likely a typo intended as "...no matching footnote."

† In some contexts, an unpaired asterisk or dagger may not refer to a footnote, and thus not constitute a mystery. Examples include programming languages and mathematical expressions using asterisks such as for the multiplication operator, and dates of birth and death which are sometimes indicated with an asterisk or dagger respectively.

#2709: Solar System Model

December 09, 2022
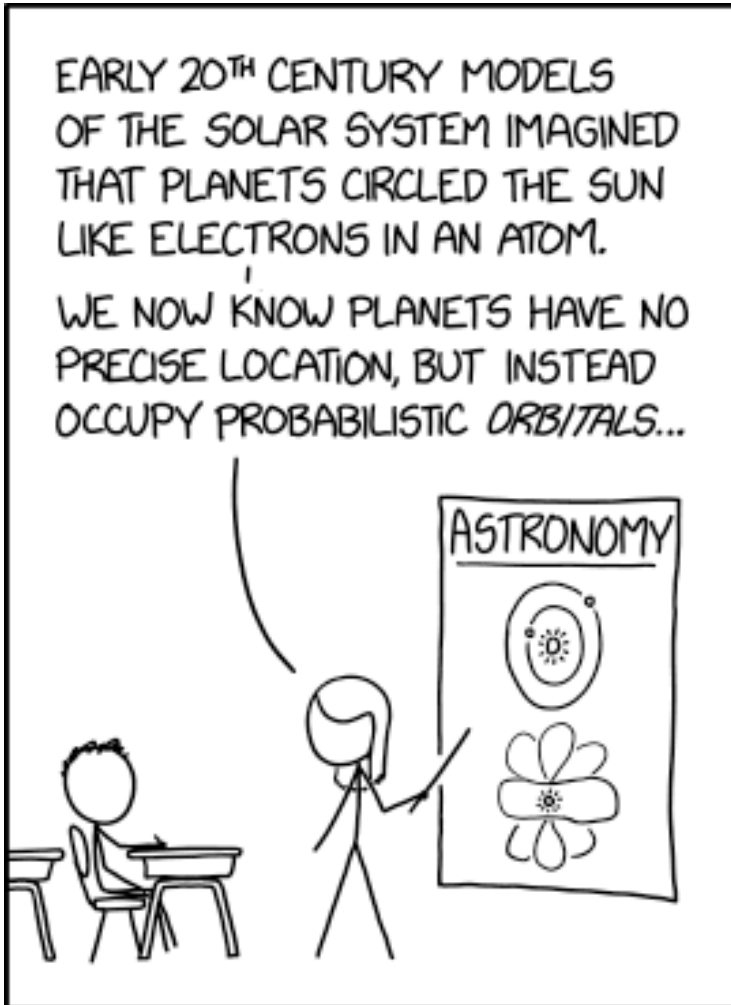
The Earth is, on average, located in the habitable zone, but at any given time it has a certain probability of being outside it, which is why life exists on Earth but is mortal.

Explanation

This comic parodies the analogy of early-20th century models of atomic structure to the structure of the solar system. Electrons were thought to be orbiting the nucleus "like planets around a sun" until it was discovered that their locations are probabilistic. The comic flips this on its head: instead of the atomic structure model lacking a known causal relationship, it is now the planetary system that is quantum mechanical in nature, split into probabilistic orbitals.

Miss Lenhart is shown here to be teaching an astronomy class, and claims that it was thought that the planets moved around the sun like electrons around the nucleus before this model was superseded by the probabilistic quantum mechanical view of orbital locations for planetary movement.

This is another one of the comics where Lenhart tries to fool her class, as in for instance 1519: Venus. Most likely it is not to be taken to be true that her world is like this, or that she believes in it. She just likes to mess with her students.

If what she said was to be taken literally it would suggests that in this reality not only do electrons have distinct bodies that orbit a nucleus, but also that atomic structure was known before the correct planetary one.

In reality, the description of probabilistic orbitals is

applied to the electrons in an atom; quantum uncertainty effects are not large enough to notice at the planetary scale[citation needed]. However, such a concept has been prominently featured in the video game Outer Wilds, with its Quantum Moon. Immanuel Velikovsky proposed that our solar system's planets could jump between orbits suddenly, quantum-mechanically, in the same way that electrons do around atomic nuclei. This proposal was not well received in academia. Real astronomers do talk about probability distributions of orbiting bodies, especially in the context of collision calculations, but it's not because the position of a satellite or asteroid is in a quantum superposition of states; rather, it is our less than infinite accuracy of measurement and knowledge of those orbits, plus their evolution under the influence of less-predictable effects like space weather or other still unidentified additional factors, that makes long-term estimates progressively more uncertain.

The title text is Miss Lenhart trying to use the first joke to set up another that builds on the first. She says that the consequence of planets having probabilistic locations would mean that they would spend some time in the lower-probability locations closer to or further from the Sun. The Earth's real orbit is in a so called habitable zone where the temperature allows liquid water and thus allows life as we know it to exist. A probabilistic Earth would spend most of its time in the habitable zone, which is why life exists, but then, in short periods when it is outside the zone, some life would die. The title text

claims this is why life on Earth is mortal, thus indirectly implying that life only dies in the periods where Earth leaves the habitable zone, and that life staying in the habitable zone would be immortal.

There was already an orbital model parody made in 2100: Models of the Atom, which featured the planetary one, but at that time it was solely for the humorous insertion of 'facts' into the subject of atomic theory.

#2710: Hydropower Breakthrough

December 12, 2022
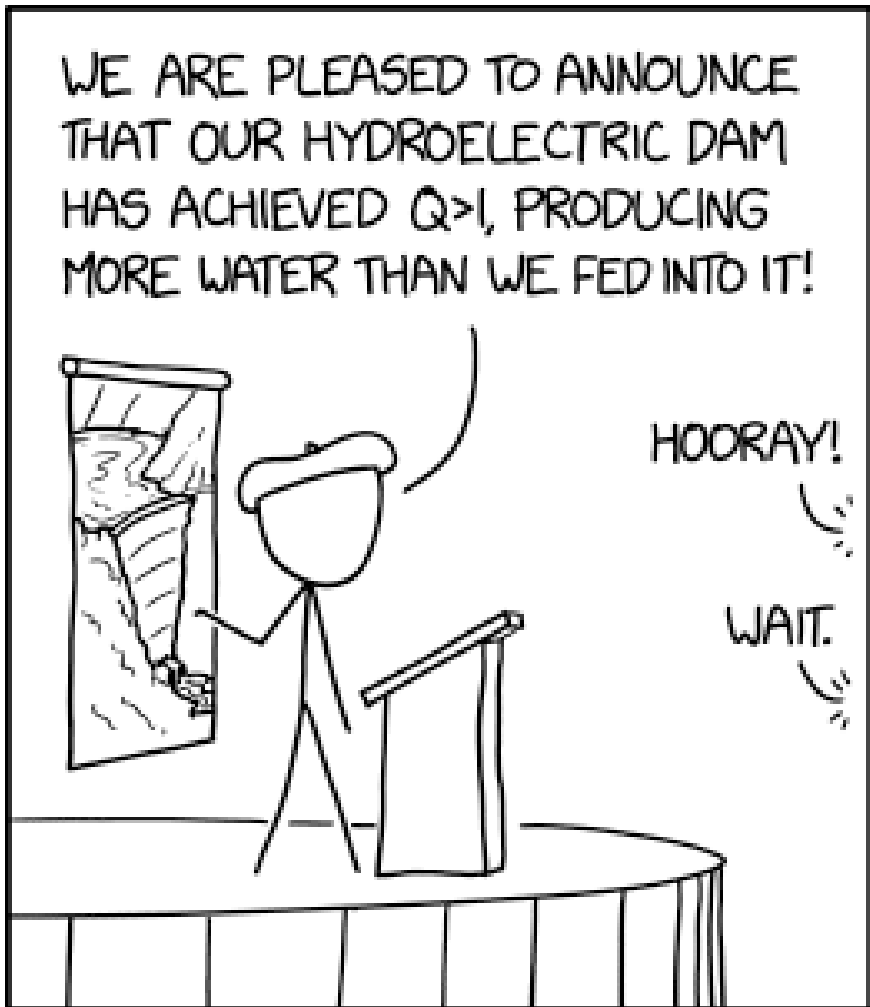
A hydroelectric dam is also known as a heavy water reactor.

Explanation

In this comic, Beret Guy announces that a hydroelectric dam has reached "Q > 1". This has two possible meanings, and the humour comes from their juxtaposition.

In fluid dynamics, the letter Q represents the volumetric flow rate, or volume of fluid per unit time, e.g. m^3/s. Depending on the units chosen, it would not be at all surprising for this number to be greater than 1 for a hydroelectric dam.

However, Beret Guy's clarification, that the meaning of this is that the dam is producing more water than was fed into it, suggests that he is interpreting the letter Q in a manner similar to its use in fusion power, where it represents the ratio of output power to input power. Typically fusion reactors require more power than they generate, but on the day after this comic was released, the US National Ignition Facility announced the first Q > 1 fusion reaction. However, hydroelectric dams work quite differently from fusion reactors,[citation needed] and (despite frequent comparisons) water is different from electricity.[citation needed]

If a dam were indeed producing more water than came into it from the reservoir and other sources, especially on a consistent basis (and not just because of water that had been stored somehow inside the dam) it would have to be doing so by chemical reaction. Anything else would be a

violation of the law of conservation of mass. For example, the dam might be catalyzing hydrogen gas to burn with oxygen in the air. Such a reaction would be dangerous to the dam. A reaction might even consume the material of the dam itself.

It appears that one of the audience members is oblivious to this fact, joining in Beret Guy's celebration, while another audience member is more effectively applying their critical thinking skills.

Alternatively, it is possible that Beret Guy is suggesting that the amount of water coming out of the dam is greater than the amount travelling into it via the penstock. If so, this indicates that water is finding other paths through the dam (a literal "breakthrough"), which is a very dangerous situation and would also be a cause for concern, not celebration.

The title text further confuses the issue by equating the hydroelectric dam with a heavy water reactor, which is a type of nuclear fission (not fusion) reactor that uses deuterium oxide, or "heavy water", as a moderator. A hydroelectric dam is powered by the weight of water, but it is not supposed to be a reactor.

#2711: Optimal Bowling

December 14, 2022
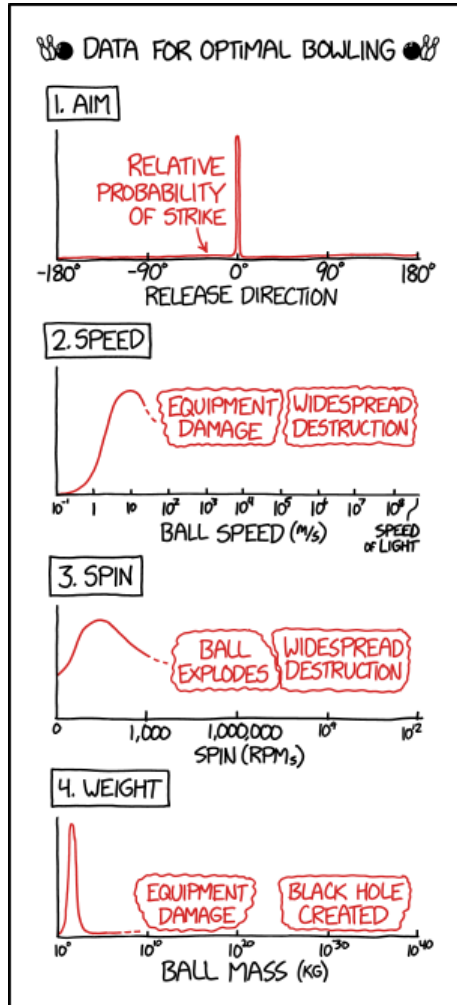
If you want to bowl a strike, the optimal place is almost certainly inside a bowling alley, although with a little luck any establishment uphill from one could also work.

Explanation

This series of line graphs purports to advise players on how to improve their odds of achieving a strike in the sport of bowling – presumably ten-pin bowling, the most popular version of the sport in the United States. Among the parameters being measured — those being angle of throw, throwing speed, spinning speed, and weight of the ball — all four graphs encompass a range far larger than would be useful for reference by a bowler. The latter three in particular are on logarithmic scales, leading up to values that are impossible for a human to achieve.[citation needed]

The first line graph indicates that a bowler has the greatest chance of achieving a strike by aiming the ball directly at the pins, with the chance of a strike decreasing rapidly as the ball is aimed to the left or the right. The closer you aim to the pins, the more likely it is you hit them.[citation needed] While a novice bowler may have difficulty achieving a 0° angle roll, their roll would still not come close to a -90° or 90° angle (due left or due right), much less a -180° or 180° angle (which, in either case, would be the opposite direction from the pins). Unlike with the other graphs, it is physically possible for a bowler to aim the ball at any angle, albeit not permissible under bowling rules; aiming the ball at an angle which deviates significantly from 0° would most likely cause the ball to end up in the gutter, while more violent or wildly aimed actions could create a risk of the ball going into one of the other lanes or missing the lanes

entirely, which could annoy, anger, or even endanger other bowlers and employees of the bowling alley.

The second graph indicates that a bowler has the greatest chance of achieving a strike by throwing the ball about 5–20 m/s (11–45 mph, 18–72 kph), with the chance of a strike decreasing as the speed is increased or decreased. Most bowlers cannot throw more than 45 m/s (100 mph or 160 kph).[citation needed] According to the graph, any throw faster than 100 m/s would cause equipment damage, and then widespread destruction several orders of magnitude later. (Possibly a reference to Relativistic Baseball.) The graph ends at the speed of light, as it is physically impossible to throw anything faster.

The third graph concerns the rotational speed of the ball. The "ball explodes" section is a reference to one of Randall's favorite equations, which is that an object cannot spin faster than the square root of its specific tensile strength. Spinning the ball any faster than this limit would cause the bowling ball to lose its structural integrity and explosively disintegrate. At particularly high speeds, the material of the ball would be flung outwards at a significant fraction of the speed of light, causing, as in the second graph, widespread destruction (possibly a reference to One-Second Day.)

The fourth graph in this comic illustrates a bowler's probability of a strike with a ball whose mass ranges from 100 kg (2.2 pounds) to close to 1010 kg (over 22 billion pounds), and continues by indicating that balls even larger than that would cause "equipment damage" (up to

1020 kg) or the creation of a black hole (starting from around 1025 kg and up). In reality, a ball would be very likely to cause equipment damage at much lower masses than 1010 kg.[citation needed] The last entry on the x-axis of this graph is 1040 kg, which is about 5 billion times the mass of the Sun. The United States Bowling Congress requires all bowling balls to weigh no more than 16 pounds (that is, a mass of no more than 7.257 kg), with no minimum weight. Hence, if the x-axis of the graph ran from, say, 0 to 8 kg, the graph might actually impart some useful information.

The title text continues the trend of providing unhelpful information by stating that the optimal place to stand when trying to bowl a strike is inside the bowling alley, but mentions the possibility of "any establishment uphill from one" working, with a little luck. This suggests the possibility of rolling the bowling ball downhill, in to the bowling alley and the pins, such as in Curious George.

#2712: Gravity

December 16, 2022

It's a long way down.

Explanation

This interactive comic promotes Randall's new book What If? 2, which was released in September and is available for purchase. You pilot a small spaceship throughout a vast area in space exploring various bodies and planets within the play area, many containing easter eggs alluding to the book What If? 2 and previous xkcd comics. The flight mechanics are Newtonian so the spaceship can use the gravity of planets to alter its trajectory or enter orbit. The spaceship has indicator circles around it which appear when a gravitational body comes into range, showing the direction towards their center of gravity and the size of the body. A circle also appears around the spaceship whenever it collides with a gravitational body, acting as a shield. The shield remains until the player orients the spaceship upright so its landing gear can deploy.

You can easily fly between planets if you pay attention to orbital mechanics: don't just floor the accelerator. The background stars show your velocity and orientation relative to the nearest gravity well. If you are having difficulties navigating space, point towards a gravity orb and accelerate for only a few seconds. Wait until the background stars spin wildly, and then reduce your velocity to 0 before gently accelerating towards the object.

With a keyboard the arrow keys rotate the spaceship and accelerate it forward and backward. You can also use the

standard first-person shooter keys 'w', 'a', 's' and 'd', and the standard vi text editor navigation keys 'h', 'j', 'k', and 'l' to control the spaceship. Despite some spaceships having no unique backward texture, they can all reverse. On mobile the comic will full screen, pressing either side of the center rotates the spaceship, and pressing in the center accelerates it forward. Various additional glitches may occur if you're playing on mobile. Having a starting position slightly below the take-off pad means you're already 'glitched' inside the planet from the off. Escaping the planet may need inverted 'accelerating' (turning perpendicular to the local vertical and thrusting backwards until you can glitch back out into more open space. You may also be trapped within the cannonball 'orbit', with seemingly inconsistent collision-detection, such that you can be sat with landing gear extended upon features (projectile tracks, etc) that seem not to count as solid for most other purposes.

There is no "universal" point of view — the bottom of the window, "down", is oriented towards the object exerting the most gravity upon the player. Multiple things found in this comic draw attention to this, such as how on Earth Ponytail says to White Hat, "I checked downforeveryoneorjustme.com and it says just me", and he replies "Yeah, I guess down isn't down for everyone." Throughout the play area are coins that change the spaceship into different rockets and non-space-based vehicles.
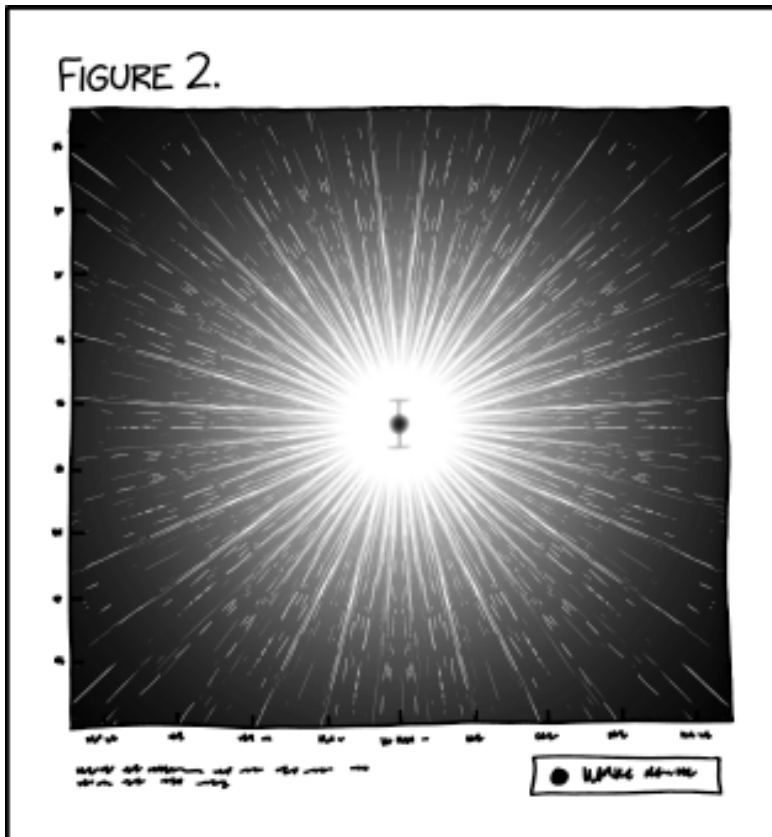
Celestial Bodies[edit]

This is a table of all the celestial bodies found in the comic.

Spaceships[edit]

This is a table of all spaceships:

#2713: Data Point

December 19, 2022

FIGURE 2.

SCIENCE POWER MOVE: WHEN ONE OF
YOUR DATA POINTS IS REALLY COOL,
DEVOTE A WHOLE FIGURE TO IT.

In general you should only include your single best data point in the paper. The rest of the data can go in the supplementary materials.

Explanation

When scientific measurements are made, the conclusions are almost always based on many data points observed in relation to each other. The comic jokes that a single data point can somehow be of such interest in isolation that the other data may be disregarded. In reality, a single datum can almost never represent what the information in the related data taken together indicate.

Randall's caption states that a figure illustrating a single datum thus constitutes a "science power move." (Similarly to the science tips of previous comics.)

This is most likely intended as facetious satire,[citation needed] because the purpose of a chart or graph figure is to present multiple data which would be less clear as tabular or textual data, so there is rarely any reason to devote a figure to a single datum, regardless of its importance. The canonical counterexample is presentation of the mean of a group of measurements. (Figure here — note the point's specular reflection indicating 3-D.) A less common counterexample might be when an interesting singular matrix decomposition such as an eigenvector is characterized, but this would only occur when such a datum is highly dimensional. It also could be a joke about papers which only highlight particularly interesting or significant data without including the background measurements or similar mundane information necessary to fully understand or reproduce the findings. While there are accepted reasons

for this practice, it can be annoying when trying to follow an otherwise useful procedure or comparing aspects of the results the authors did not anticipate.

The title text suggests relegating all the other data to supplementary materials, presumably to avoid detracting from the single "cool" datum.

#2714: Cold Complaints

December 21, 2022
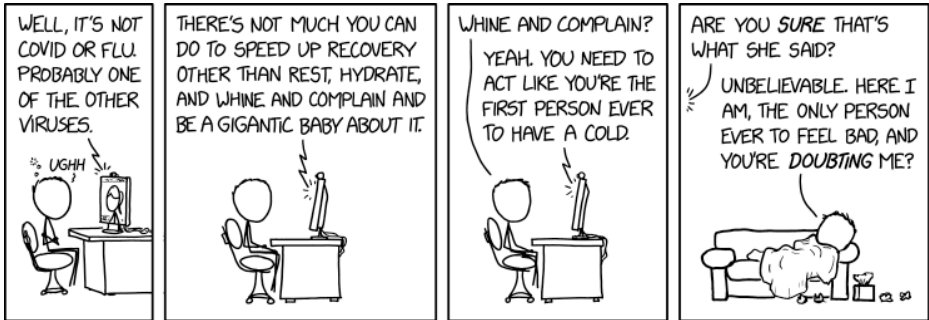
Our investigation into whining-based remedies became the first study to be halted by the IRB on the grounds that the treatment group was 'too annoying.'

Explanation

When people are ill, they will often complain about the symptoms that they're suffering from. A common stereotype is that men will revert to infantile behavior when miserably sick. This can be annoying to the people around them, but they typically tolerate such behavior out of compassion. The joke in this comic is that Hairy spoke via a telehealth appointment to Ponytail, a medical professional who explicitly advised him to act out, since his condition has no effective medical treatment. He takes her advice to "act like you're the first person ever to have a cold" literally, stating it specifically when his companion asks about it. Given xkcd's humor in the past, this may be supposed to trick the cold virus into thinking that it has not had a lot of time to evolve to infect human cells effectively so that it does not infect Hairy's cells as effectively.

Alternatively, Hairy might be making up the doctor's advice to justify his behavior. This interpretation adds to the humor by suggesting that Hairy is pretending a medical professional told him to act like a baby to excuse his exaggerated complaints. The off-screen person's doubt highlights how absurd his claim is. This fits with XKCD's typical humor, which often mixes rational and absurd elements.

This comic was published during a "tripledemic" in the U.S., involving COVID-19, influenza, and respiratory syncytial virus (RSV, a frequent cause of common colds)

infections, the latter of which do not have readily available effective treatments, other than to wait them out with plenty of rest and fluids (provided that symptoms do not require hospitalization). It expounds on the finding that "talking about troublesome events, including events with which one is dissatisfied, may ... result in improved physiological health." (Kowalski, R.M. (2002) "Whining, griping, and complaining: positivity in the negativity" Journal of Clinical Psychology 58(9):1023–35.)

The title text describes a similar study, but where the institutional review board (IRB) halted the study because the participants were too annoying. This is ironic since they were supposed to whine annoyingly for the sake of the experiment. IRBs are expected to review the ethics of a research project, with particular attention paid to the well-being of the subjects. Whining is not usually considered dangerous,[citation needed] but in this case it was presumably so intolerable to the Board (or perhaps the control group, who were presumably forbidden from whining while sick) that they had to put a stop to it.

#2715: Pando

December 23, 2022
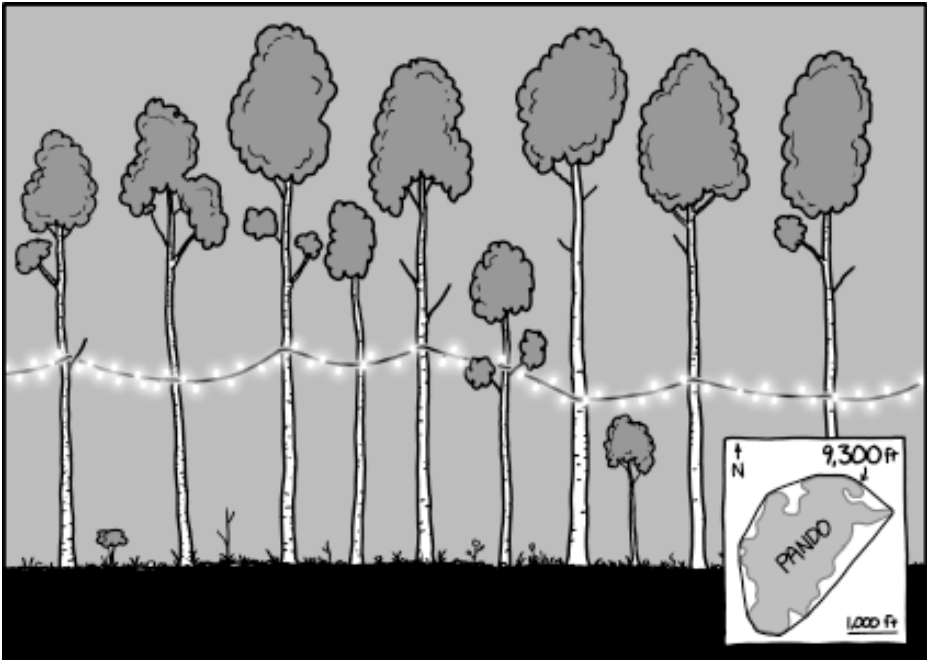
CHRISTMAS SCIENCE FACT: PANDO IS APPROXIMATELY 9,300 FEET OF LIGHTS AWAY FROM BEING THE WORLD'S LARGEST CHRISTMAS TREE.

The presents under the tree are actually a single gift connected by an underground ribbon system.

Explanation

This comic was the Christmas comic of 2022 published on the 23rd of December, two days before Christmas, or Christmas Eve Eve. Christmas is a celebration on the 25th of December, traditionally commemorating the birth of Jesus.

Pando is a clonal colony made of quaking aspen trees in Fishlake National Forest, Utah. Depending on the measurement method (there being various options), Pando is the largest living organism on earth, and is thereby also the largest tree on earth. There is one fungus in Oregon which may weigh more including water, but a fungus is not a tree.

Clonal colonies all form from the same seed or other origin, and are all genetically identical. Tree colonies spread using their extensive root system. On clonal trees, when roots from one tree surface they can form another stalk/tree, remaining the same genetic stock; this is unlike propagation by seeds. This clone then grows its own root network and is part of the clonal colony. Crucially, the linking roots between 'generations' of the plant do not naturally separate, so all effective clones stay attached an as such form one huge organism. Each such stalk still has an individually limited lifespan of decades to centuries, but the colony can persist and propagate in this manner for millennia. For example, the only known wild example of Lomatia tasmanica, also known as King's lomatia, is a clonal shrub thought to be at least 43,600 years old, and

Pando itself is thought to be around 14,000 years old.

The concept of a Christmas tree is rooted in various pre-Christian folkloric traditions and, in the modern era, may be adapted or adopted as desired by local and personal circumstances. It need not be an evergreen tree with an angel or star atop, though that is the oft-depicted image, but can be any handy plant or artificial substitute strewn with decorations and/or lights as the owner wishes. People and places often compete to hold the record for the largest Christmas tree. At time of writing, the officially tallest Christmas tree was a 64.36 m (221 ft) tall Douglas-fir that was displayed in Northgate Shopping Center, Seattle, WA in 1950. The one with the most area is likely the Christmas tree display in Gubbio, a town in Umbria, Italy, where hundreds of trees on a mountain face are lit up with light to form a Christmas tree shape.

In this comic, Randall proposes putting Christmas lights all the way around Pando to turn it into (technically) a Christmas tree. As Pando is the world's largest tree, if this plan were carried out, it would safely take the record for largest Christmas tree and hold it for quite some time. In the inset map, Randall has drawn the path of the Christmas lights as a convex hull around the edge of Pando. Roughly tracing Pando on Google Maps reveals its perimeter to be roughly 2.77 km or 1.72 miles, or roughly 9,000 ft. Allowing a little wiggle-room for differing levels of accuracy, and possibly the extra length required to suspend the shallow catenary loops of the lights and wrap them around the various supporting

branches, 9,300 ft of Christmas lights seems about right.

The title text suggests that similarly to how trees that make up Pando are interconnected by underground roots, the gifts under the proposed Christmas tree are interconnected by underground ribbons. It may also be a reference to fungus, which often grow beneath trees, and can be connected by vast underground mycelial networks, suggesting that the christmas presents are the fruiting bodies of a similar network (perhaps a reference to 2246: Christmas Presents).

#2716: Game Night Ordering

December 26, 2022
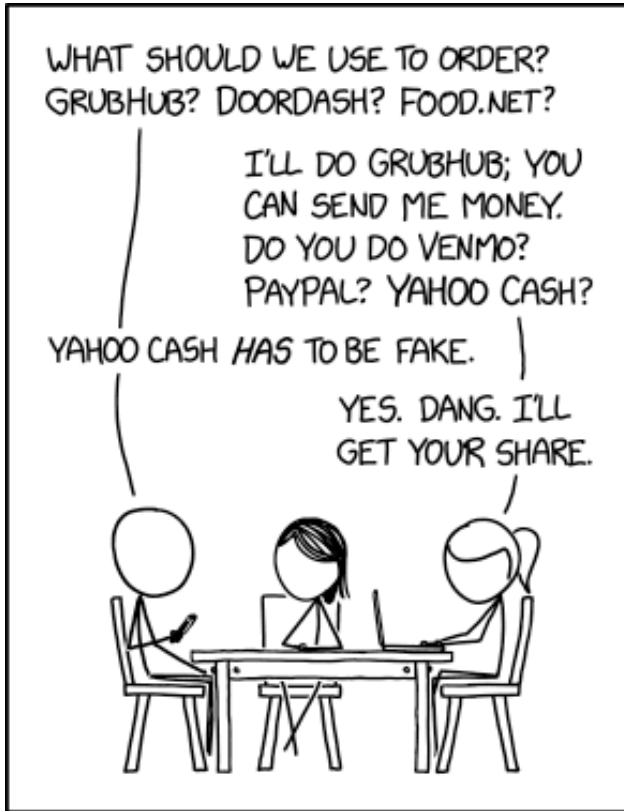
OUR GAME NIGHT HAS AN ONGOING COMPETITION TO SEE WHO CAN MENTION THE MOST FAKE APPS AND SERVICES WITHOUT GETTING CALLED ON IT.

One good trick, if you get called on a fake service, is to build a working version of it and mention it again the next week.

Explanation

This comic is poking fun at the proliferation of apps and internet services such as for food delivery and money transfer. The characters are discussing which to use during an evening of tabletop gaming. The group has a running competition to see who can mention fake apps or services without being called out. The idea being that, since there are so many, it is difficult to identify which are real.

Cueball mentions three food delivery services, Grubhub, DoorDash, and Food.net, and Ponytail asks him to reimburse her using Venmo, PayPal, or Yahoo Cash. Cueball expresses skepticism about Yahoo Cash, after which Ponytail admits it's a fake service (it's a spoof of Google Pay) and is thus obligated to pay for Cueball's meal. (Incidentally, Yahoo does provide a money transfer service to facilitate private party gambling on fantasy sports, called Yahoo Fantasy Wallet, but it uses PayPal.) Food.net, which Cueball mentioned without being called out, is not a real service; https://food.net exists, however, it is not related to food delivery.

Based on Ponytail's offer, if someone is correctly called out, they must pay for the player who caught them. If a player isn't caught, like when Cueball mentions Food.net, nothing happens. Ponytail is too afraid to call him out on this, and decides to order from a service that she knows exists, Grubhub, and then tries to bluff the others using strange payment methods.

It is not explained in the comic, but you probably also have to pay for the other person's food if you call a bluff, and it turns out the service did indeed exist. So if Megan had said to Cueball, "Grubhub? That must be fake," and he then proved that it exists (by ordering there), then Megan would most likely be obliged to pay for Cueball's food.

The title text offers a tip for winning the competition next week after being called out for mentioning a fake service: building a working version and then mentioning it again next week. While it could be possible to prototype a user interface and possibly use it to perform food deliveries with a very limited number of drivers in a small area, or provide a front-end interface to an existing money transfer service with strong API support, building a full-fledged viable service for either in a week is humorously beyond the reach of typical gamers. Also, as in Ponytail's case, it could cause trademark issues with brand names.

#2717: L6 Lagrange Point

December 28, 2022
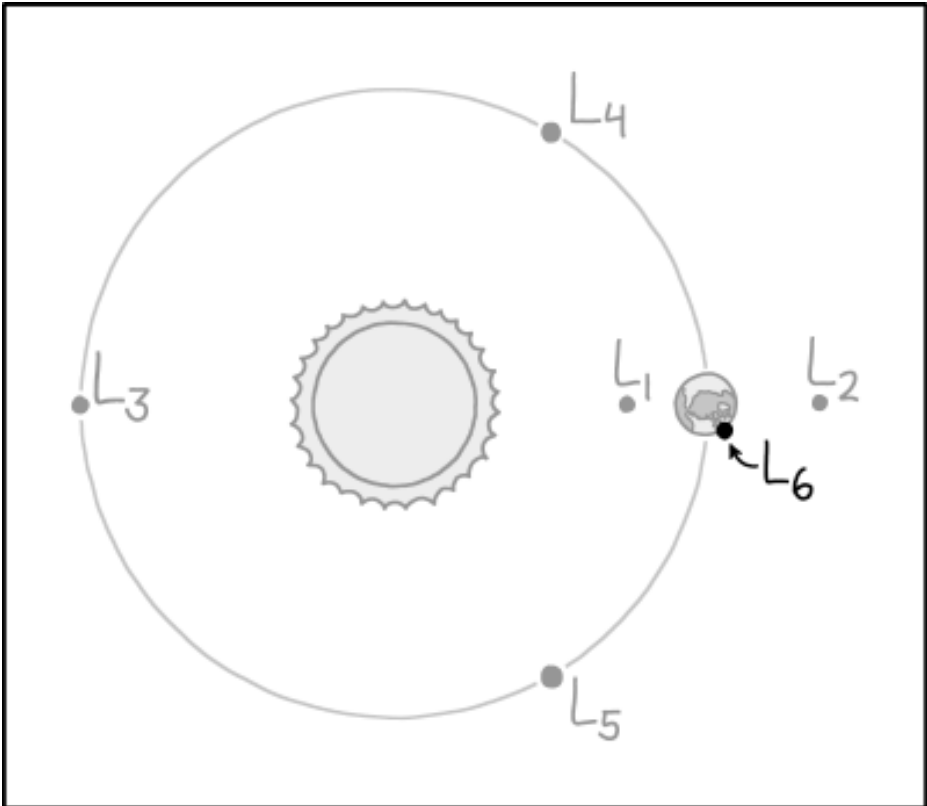
HUGE SPACE NEWS: ASTRONOMERS HAVE DISCOVERED
A NEW LAGRANGE POINT JUST OUTSIDE CLEVELAND.

It's difficult to orbit L6 stably due to gravitational
perturbation from Akron and Toledo.

Explanation

In celestial mechanics, the Lagrange points are points of equilibrium for small-mass objects under the influence of two massive orbiting bodies. Or in simpler terms, positions in space where objects can float motionless relative to the defining bodies.

There are five traditional Lagrange points. Two form equilateral triangles with the two massive objects (in this case the Earth and the Sun), and three more are collinear with the massive objects. The L1, L2, and L3 points are unstable, as any drifting off the point (e.g. due to the gravity of other bodies) might quickly increase the tendency to depart the area. However, there are quasi-stable Halo orbits around these points, like the one used by the James Webb Space Telescope. The L4 and L5 points can actually retain objects stably over long periods, resulting in the Sun-Jupiter L4 and L5 points capturing the Trojan Asteroids.

Randall claims that a sixth Lagrange point has been discovered outside of Cleveland, Ohio. This is pretty obviously farcical,[citation needed] as this would be part of the Earth and thus not gravitationally balanced between Earth and the Sun, though it is balanced by the countering forces that hold anything stable on the surface of any body: gravity and electromagnetism. The joke here is that there actually is a small village named LaGrange, OH (population 2,595 in 2020) just outside Cleveland (map). However, the village name is spelled

with a capital G, unlike Joseph-Louis Lagrange after which the Lagrange points were named.

There is, however, a Lagrange in Maine, a Lagrange in Virginia and a Lagrange Township in Illinois which all use the lower case g in their spelling like Joseph-Louis Lagrange. There are also twenty-six other communities in the United States with a spelling of LaGrange or La Grange, as well as four in France and two in Australia with one of the three spellings. This includes La Grange, Texas which became famous as the title of a ZZ Top song.

The title text mentions Akron and Toledo, two other large cities in Ohio. It says that their gravitational influence is the reason why orbits around the LaGrange L6 are unstable. The Lagrange points are solutions for a simplified three-body system, and orbits around them may be disrupted if additional bodies such as moons or planets are close enough or massive enough to cumulatively exert significant gravitational forces over time (the Moon does factor into the Earth-Sun L1 and L2 Lagrange points, especially, but that can be accounted for in the station-keeping measures already required). Trying to orbit around a point on the ground would, of course, run into much more serious problems, such as the ground.

#2718: New Year's Eve Party

December 30, 2022

HEY ROB! OR, UH...
SORRY, IS THAT MIKE?
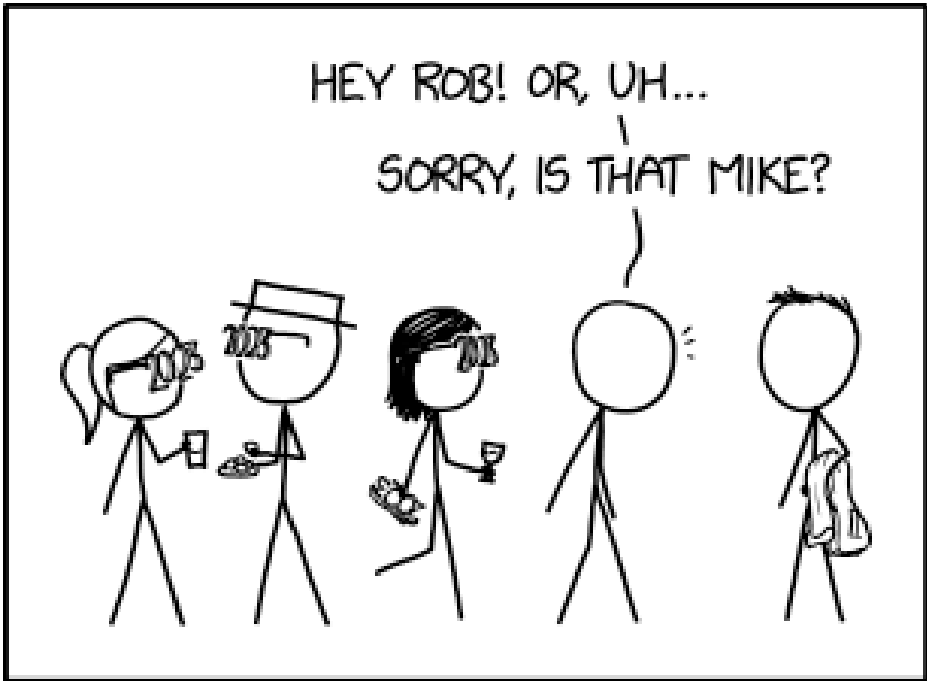
I'M REGRETTING MY NEW YEAR'S EVE NOVELTY "2023" LASER EYE SURGERY.

[Earlier, at the eye doctor] 'No, for the last time, the numerals on the paper aren't my prescription, it's the shape I want you to make with the laser.'

Explanation

New Year's glasses are novelty eyeglasses typically worn at New Year's Eve parties, shaped like the digits of the upcoming year. They were popularized in the late 1990s and early 2000s since the middle digits (9 and 0) had holes large enough to look through or mount lenses into.

Ponytail, White Hat, Megan and Cueball are at a party. The first three are wearing novelty glasses in the shape of the numerals "2023", representing the upcoming New Year. Cueball has chosen to obtain cosmetic laser eye surgery instead. Usually, such procedures are intended to adjust a patient's corneas to correct vision problems, as an alternative to glasses and contact lenses. Cueball has apparently had the digits 2023 etched into his eyes as an alternative to wearing novelty glasses. While scleral tattooing is performed for cosmetic reasons, and corneal tattooing for both cosmetic and vision benefits, the efficacy and safety of either process is not universally accepted. The laser procedure has damaged Cueball's vision so much that he mistakes a newcomer to the party resembling Hairy as Rob. Realizing he made a mistake, his second guess is that the new arrival is named Mike.

In the title text, an earlier conversation with his ophthalmologist has established Cueball's problems are due to the laser burning the digits straight onto his eyeballs, without regard to endangering his vision. Most previous depictions of Cueball have not shown him wearing glasses. Laser eye surgery was referenced along

with other laser equipment in 1681: Laser Products.

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